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ASSAYING  
OF  
GOLD, SILVER, COPPER AND LEAD  
ORES.





MANUAL OF ASSAYING

GOLD, SILVER, COPPER

AND

LEAD ORES.

By WALTER LEE BROWN, B.Sc.

WITH ILLUSTRATIONS.

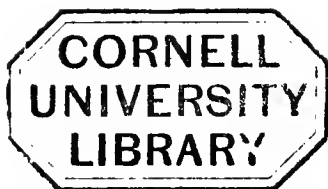


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## PREFACE.

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WHEN I entered upon the task of preparing this book, it was with the idea of furnishing a guide to those, who, having had no previous technical or especially scientific education, desired to learn something of the *practical assaying of gold and silver ores*, and in whose hands I could place no work that could give them this information in a clear, simple and thoroughly detailed manner, and unburdened with unnecessary matter.

This intention I have tried to adhere to all the way through, and while I have added other information which was pertinent, I have kept such increase in an appendix, so that the body proper of the work contains the real subject matter.

It is my sincere belief that there is no book in the English language on the subject of assaying which occupies the space that this little manual tries to fill.

A number of such publications fail to meet the want, on account of their antiquity, they having been written some thirty years back ; hence their methods, apparatus, etc., are not suited to the assayers of to-day. Others are either more suitable as books of reference, or do not give sufficient detail for the inexperienced.

It is this latter fault I have carefully endeavored to avoid, and perhaps have gone to the other extreme. At all events, I have tried to give here in print the

precise instruction which I have previously imparted orally to my students. Those who may choose to criticise, will remember for whom this hand-book is written.

While I have consulted many of the authorities listed on pp. 268-74, it is from three in particular that I have drawn great help. I refer to Mitchell's Manual of Practical Assaying, Ricketts' Notes on Assaying, and Kustel's Roasting of Gold and Silver Ores.

Besides the above, and other printed sources referred to in their proper places, I wish to publicly thank the following gentlemen who have very kindly aided me in my work with valuable information: Mr. S. A. Reed, Irwin, Colo.; Mr. A. H. Low, Assayer of the Boston and Colorado Smelting Works, Argo, Colo.; Mr. C. Boyer, Assayer of the U. S. Branch Mint, Denver, Colo.; Mr. M. G. Nixon, Engineer, and Mr. R. G. Coates, both of Chicago.

In conclusion I trust that all those who are willing to aid me in the preparation of an improved edition of this book, will at once communicate with me.

WALTER LEE BROWN,

Analytical and Consulting Chemist and Assayer,  
105 Metropolitan Block, Chicago, Ill.

March, 1883.

# CONTENTS.

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## PART I.

### APPARATUS AND RE-AGENTS.

#### CHAPTER I.

##### APPARATUS USED IN ASSAYING.

IMPLEMENTS FOR PULVERIZING, SAMPLING, ETC.,	18
SCALES AND BALANCES,	28
WEIGHTS,	39
FURNACES,	42
FURNACE TOOLS,	59
APPARATUS USED IN THE FURNACE,	68
APPARATUS OF GLASS AND PORCELAIN,	77
MISCELLANEOUS APPARATUS,	81

#### CHAPTER II.

##### RE-AGENTS USED IN ASSAYING.

DRY RE-AGENTS FOR ASSAYING,	93
WET RE-AGENTS FOR ASSAYING,	106
RE-AGENTS FOR ANALYSIS,	108

#### CHAPTER III.

##### TESTING OF RE-AGENTS; PRELIMINARY WORK.

I. TESTING OF LITHARGE FOR SILVER,	116
II. TESTING OF GRANULATED LEAD FOR SILVER,	118
III. TESTING OF SHEET LEAD FOR SILVER,	120
IV. DETERMINATION OF THE REDUCING POWERS OF REDUCING AGENTS,	121
V. DETERMINATION OF THE OXIDIZING POWER OF NITRE (NITRATE OF POTASH),	122
VI. DETERMINATION OF THE REDUCING POWERS OF CERTAIN ORES,	123

## PART II.

## ASSAYING.

## CHAPTER I.

## GOLD AND SILVER ORES.

OCCURRENCE,	- - -	129
ASSAY, - - -	- - -	132
I. PREPARATION OF THE SAMPLE,	-	133
II. SCORIFICATION PROCESS,		139
<i>a.</i> Preparation of Charge, 141; <i>b.</i> Scorification, 146; <i>c.</i> Cupellation, 152; <i>d.</i> Weighing the Gold and Silver Bead, 160; <i>e.</i> Parting, 161; <i>f.</i> Inquartation, 164; <i>g.</i> Weighing the Gold Residue, 165; <i>h.</i> Calculations, 166.		
III. CRUCIBLE PROCESS,		170

## CHAPTER II.

## COPPER ORES.

OCCURRENCE,		180
ASSAY, - - -	- - -	181
I. METHOD FOR NATIVE COPPER,		182
II. METHOD FOR OXIDES AND CARBONATES OF COPPER, FREE FROM SULPHUR,	- - -	182
III. METHOD FOR SULPHIDES OF COPPER, WITH ARSENIC, ANTIMONY, ETC.,		183

## CHAPTER III.

## LEAD ORES.

OCCURRENCE,	- - -	185
ASSAY, - - -	- - -	186
I. METHODS FOR GALENA,		186
II. METHODS FOR OXIDES AND CARBONATES,		194

# APPENDIX.

## SECTION I.

### SPECIAL METHODS.

I. ASSAYING OF THE VARIOUS MINERALS CONTAINED IN AN ORE,	201
II. ASSAYING OF ORES CONTAINING FREE GOLD OR FREE SILVER, . . . . .	203
III. ANALYSIS OF COPPER ORES, . . . . .	210
IV. AMALGAMATION ASSAY OR LABORATORY MILL RUN,	221
V. PAN TEST FOR GOLD ("PANNING"), . . . . .	225
VI. CHLORINATION ASSAY OF GOLD ORES,	234
VII. CHLORINATION TEST FOR SILVER, . . . . .	237
VIII. THE ASSAY OF GOLD BULLION, . . . . .	239
IX. THE ASSAY OF BASE BULLION,	243
X. COLOR TESTS; SCORIFICATION, SCORIFIER, CUPEL,	246
XI. QUALITATIVE TESTS; CARBONATES, CHLORIDES, SUL- PHATES, SULPHIDES, TELLURIDES, COPPER, IRON, LEAD, SILVER, . . . . .	249
XII. BRIEF SCHEME FOR SILICA, IRON AND MANGANESE,	254
XIII. DETERMINATION OF MOISTURE IN AN ORE,	255

## SECTION II.

### LISTS AND REFERENCES.

LIST OF THE PRINCIPAL GOLD MINERALS FOUND IN THE UNITED STATES,	257
MINERALS LIKELY TO CARRY GOLD, . . . . .	258
LIST OF THE PRINCIPAL SILVER MINERALS FOUND IN THE UNITED STATES, . . . . .	258
MINERALS LIKELY TO CARRY SILVER,	261
LIST OF THE PRINCIPAL COPPER MINERALS FOUND IN THE UNITED STATES, . . . . .	262

LIST OF THE PRINCIPAL LEAD MINERALS FOUND IN THE UNITED STATES,	265
LIST OF USEFUL BOOKS ON SUBJECTS MORE OR LESS CONNECTED WITH ASSAYING: GENERAL SCIENCE; GENERAL CHEMISTRY; CHEMICAL TECHNOLOGY; REFERENCE BOOKS ON CHEMISTRY; TEXT-BOOKS ON THEORETICAL CHEMISTRY; GENERAL QUALITATIVE ANALYSIS; GENERAL QUANTITATIVE ANALYSIS; SPECIAL QUANTITATIVE ANALYSIS; VOLUMETRIC ANALYSIS; LABORATORY MANIPULATION; GEOLOGY; MINERALOGY; BLOW-PIPE ANALYSIS; METALLURGY AND MINING; ASSAYING; METRIC SYSTEM—WEIGHTS AND MEASURES; MINING LAW,	268
FORM FOR CERTIFICATE OF ASSAY, - - -	275
OUTFIT, - - - -	276

## SECTION III.

## TABLES.

MULTIPLICATION TABLE FOR GOLD AND SILVER,	279
TABLE OF VALUES OF GOLD AND SILVER, - -	280
TABLES OF WEIGHTS: AYOIRDUPOIS; TROY; APOTHECARIES'; FRENCH OR METRIC SYSTEM, - -	281
EQUIVALENTS OF SOME OF THE ENGLISH AND FRENCH WEIGHTS, - - - -	285
ASSAY TON EQUIVALENTS IN GRAMMES, TROY GRAINS AND TROY OUNCES, - -	286
INDEX, - - - - -	297



# INTRODUCTION.

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In our present state of knowledge we believe all matter to be composed of one or more elements or original simple substances.

These elements are considered to be sixty-five in number. Certain of them have what we may call a *commercial importance*. (See Introduction to Attwood's Blow-pipe Assaying.) They are as follows, the metals being in *italics*:

- |                      |                        |
|----------------------|------------------------|
| 1. <i>Aluminium.</i> | 16. <i>Gold.</i>       |
| 2. <i>Antimony.</i>  | 17. Hydrogen.          |
| 3. Arsenic.          | 18. Iodine.            |
| 4. <i>Barium.</i>    | 19. <i>Iridium.</i>    |
| 5. <i>Bismuth.</i>   | 20. <i>Iron.</i>       |
| 6. Boron.            | 21. <i>Lead.</i>       |
| 7. Bromine.          | 22. <i>Lithium.</i>    |
| 8. <i>Cadmium.</i>   | 23. <i>Magnesium.</i>  |
| 9. <i>Calcium.</i>   | 24. <i>Manganese.</i>  |
| 10. Carbon.          | 25. <i>Mercury.</i>    |
| 11. Chlorine.        | 26. <i>Molybdenum.</i> |
| 12. <i>Chromium.</i> | 27. <i>Nickel.</i>     |
| 13. <i>Cobalt.</i>   | 28. Nitrogen.          |
| 14. <i>Copper.</i>   | 29. Oxygen.            |
| 15. Fluorine.        | 30. <i>Palladium.</i>  |

- |                       |                       |
|-----------------------|-----------------------|
| 31. Phosphorus.       | 39. <i>Tin.</i>       |
| 32. <i>Platinum.</i>  | 40. <i>Titanium.</i>  |
| 33. <i>Potassium.</i> | 41. <i>Tungsten.</i>  |
| 34. Silicon.          | 42. <i>Uranium.</i>   |
| 35. <i>Silver.</i>    | 43. <i>Vanadium.</i>  |
| 36. <i>Sodium.</i>    | 44. <i>Zinc.</i>      |
| 37. <i>Strontium.</i> | 45. <i>Zirconium.</i> |
| 38. Sulphur.          |                       |

Some of the above are valuable in themselves, others in combination.

The remainder of the elements, which have no especial value excepting perhaps as curiosities, are :

- |                       |                       |
|-----------------------|-----------------------|
| 1. <i>Cæsium.</i>     | 11. <i>Osmium.</i>    |
| 2. <i>Cerium.</i>     | 12. <i>Rhodium.</i>   |
| 3. <i>Columbium.</i>  | 13. <i>Rubidium.</i>  |
| 4. <i>Davyum.</i>     | 14. <i>Ruthenium.</i> |
| 5. <i>Didymium</i>    | 15. <i>Selenium.</i>  |
| 6. <i>Erbium.</i>     | 16. <i>Tantalum.</i>  |
| 7. <i>Gallium.</i>    | 17. <i>Tellurium.</i> |
| 8. <i>Glucinum.</i>   | 18. <i>Thallium.</i>  |
| 9. <i>Indium.</i>     | 19. <i>Thorium.</i>   |
| 10. <i>Lanthanum.</i> | 20. <i>Yttrium.</i>   |

Besides the sixty-five elements above enumerated, there are some eight or ten extremely rare metals (decipium, holmium, mosandrium, norwegium, philippium, samarium, scandium, terbium, thulium, ytterbium,

etc.), whose existence is not yet quite satisfactorily proven.

In order to ascertain the value of an ore, it is necessary to determine the percentage of the metal or metals which it contains.

This is the first thing to be done—an after consideration is the question of the presence of other ingredients which may injuriously affect the value of the ore or product.

There are two general methods, known respectively as *assaying* and *analysis*, whereby we may test an ore to learn its composition.

A comprehensive definition of assaying is to call it that branch of exact science which enables us to find out of what a substance is composed and the proportions, by means of *dry* re-agents and *heat*.

On the other hand, analysis is that branch which effects the same results mainly by the use of *wet* re-agents, with or without the aid of heat.

In spite of this distinction, *wet assays*, as opposed to *dry* or *fire assays*, are continually spoken of; still, to be as consistent as possible, the terms assaying and analysis, as defined above, will be used throughout this work.

The greater number of the processes given in this little book come under the former heading, while analysis proper is employed in only a few cases.

The following metals are sought for in ores by assaying: antimony, bismuth, cobalt, copper, gold, iron, lead, nickel, platinum, silver, tin and zinc.

It is the object of this manual to treat only of gold, silver, copper and lead. For information concerning the assaying of the remaining metals just mentioned, the student must seek it on page 273, among the various works on assaying there quoted.

PART I.

APPARATUS AND RE-AGENTS.



# MANUAL OF ASSAYING.

## PART I.

### APPARATUS AND RE-AGENTS.

---

## CHAPTER I.

### APPARATUS USED IN ASSAYING.

IT is as true of the art of assaying as of any other, that "good work requires good tools." While many of the latter can be dispensed with by the skilled assayer, it is often convenient, if not absolutely necessary, for the unskilled to have the best utensils for the work required.

I shall therefore give an exhaustive list of apparatus needed for the processes herein described, but shall try to avoid mentioning many implements which are not essential.

## IMPLEMENTS FOR PULVERIZING, SAMPLING, ETC.

*Iron Mortars and Pestles.*—Two sizes of mortars are handy, a large one 11 inches in diameter, and weighing with pestle about 35 pounds (2 gallons capacity), and a smaller one of 5 inches diameter and 7 pounds weight ( $\frac{1}{2}$  gallon capacity). Instead of both, a



medium size, 8 inches diameter, in weight about 19 pounds (1 gallon capacity), may be employed. They may be either bell or urn-shaped.

FIG. 1.

Care should be taken to remove all ore from the mortars after grinding. Generally an old towel, rag, or even paper, will suffice to do this, but occasionally washing must be resorted to. Dry thoroughly after the latter operation. Triturating with dry sand often answers the purpose. When not in use let the mortars rest mouth downward.

*Crushers.*—These are intended to take the place of the mortar and pestle for crushing comparatively large quantities of ores. For small samples the mortar will do very well,



but for say 20 pounds and upward, some sort of a crusher will be a desideratum. Especially will it be needed in a large assay laboratory.

There are quite a number of hand crushers in the market intended solely for laboratory purposes, such as the Alden, Blake, Forster, Lipsey, etc.

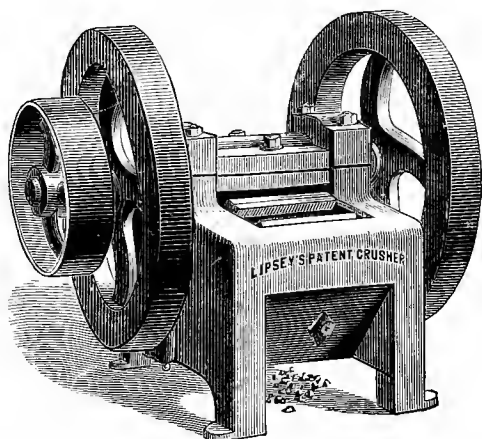


FIG. 2.

Among the best is the Lipsey, which is represented in full in fig. 2, and in section in

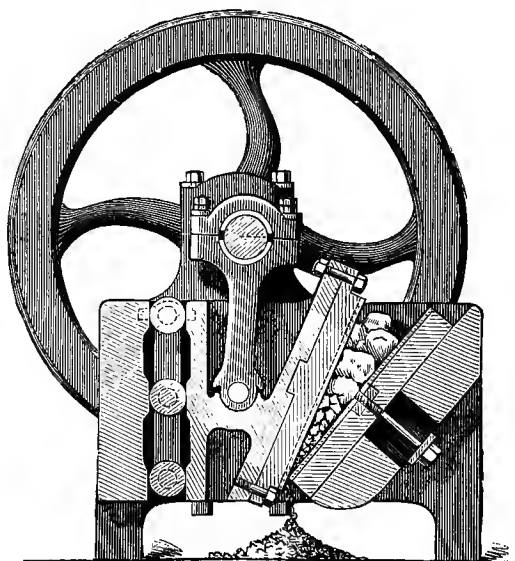


FIG. 3.

fig. 3. It can be turned either by hand or power.

The value of whatever crusher is employed will depend mainly upon the ease, rapidity and *thoroughness* with which it can be cleaned.

Certain special apparatus, as hand-stamps and pulverizers, must be left to the necessities and preferences of the individual assayer.

*Pulverizing Plate and Rubbers.*—These are so useful and convenient that they can hardly

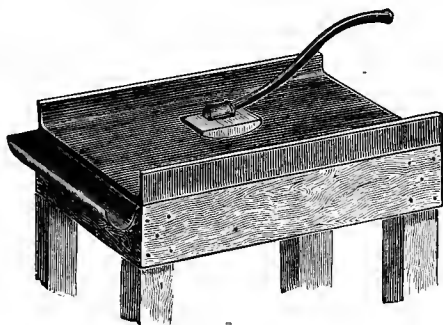


FIG. 4.

be dispensed with ; in fact, if much assaying is to be done, they will become absolutely necessary. They are represented in fig. 4. The iron plate, which should be perfectly true and have a smooth surface, is made of varying dimensions, as  $12 \times 12$ ,  $18 \times 24$ ,  $23 \times 24$ ,  $24 \times 24$ ,  $24 \times 30$  and  $24 \times 36$ , in inches. It is made with no protecting rims, or with rims at the sides only (as figured), or with a rim at each side and at one end, leaving one end open. In some cases the side rims gradually shallow

from the back to the front. The size I use, and with which I have no fault to find, is  $18 \times 24$  inches (inside measurement); thickness of bottom, 1 inch; rims,  $\frac{3}{4}$  inch wide and  $1\frac{1}{4}$  inches high; weight, 150 pounds.

(The only improvement I can suggest would be to have the back corners rounded instead of being right angles, in order to facilitate the removal of pieces of ore and the dust. Or the rims might be cast at an angle of say  $30^\circ$  instead of being perpendicular to the surface.)

The rubber, rocker, pulverizer; grinder, muller, bucking-hammer (by which various names it is known), to go with above plate, is 8 inches long and 4 wide; thickness at ends,  $1\frac{1}{8}$  inches; in centre,  $2\frac{1}{8}$ ; surface true and smooth; weight about 14 pounds. Other rockers made are, in general dimensions,  $4 \times 5$ ,  $4 \times 5\frac{1}{2}$ ,  $4 \times 6$ ,  $6 \times 7$  and  $8 \times 10$  inches.

An axe-handle is fitted into the socket on top of rocker, and then it is ready for use.

The operation of grinding, or rubbing, or

pulverizing, is managed as follows: The ore, previously broken into fine pieces as directed, is placed upon the *clean* surface of the plate, the rocker is now laid upon it, and, with one hand firmly pressed upon the body of the rocker, and the other grasping its handle, it is moved backward and forward with an oscillating motion. This knack of grinding, although not easy to describe, is soon acquired.

When a very hard ore is to be pulverized, it can much more quickly be finished with an 8x10 rocker, weight 60 pounds. The additional weight and greater width have a marked effect. An intermediate size of about 30 pounds weight would not be amiss.

Clean the plate and rockers after use with old rags or by grinding sand as in the case of the mortars.

A substantial table or frame work will be wanted upon which the plate is to be set at the proper height for working, and parallel with the floor.

In Mr. S. A. Reed's laboratory the plate is

set at an angle inclining toward the operator so as to allow of more effective pressure at the bottom, and slipped under the front end of the plate is a trough or gutter of sheet-tin or zinc, as shown in the figure. Its object is to catch any particles that may roll down the plate, and after the sample has been pulverized, the whole of the powder is brushed down into it. The trough is easily detached from the plate and its contents can then be brushed into a sieve. This simple device may replace one of the zinc sifting pans spoken of elsewhere.

*Sample Shovels.*—A pitch-fork with each tine transformed into a narrow trough would give a fair idea of the appearance of one of these shovels. A better form consists of two troughs from four to six inches deep united, with a space between, and provided with a long handle. These implements are more needed in sampling works proper than in the ordinary laboratory.

*Samplers* (also known as dividers). — One



FIG. 5.

form of these is shown in fig. 5, and consists of a frame with partitions running lengthwise at equal distances apart, and having each alternate space covered at the bottom. It is made of tin or copper, and it is well to have three sizes. A second pattern

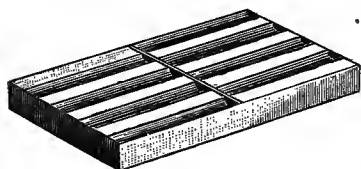


FIG. 6.

is represented in fig. 6. The first form, however, is preferred, as being more durable.

To use either, sprinkle over and across the broken ore to be sampled, and retain that which catches in the troughs.

A pulp is sometimes sampled by the use of a sampler of tin, having troughs  $\frac{1}{8}$  inch in diameter and  $\frac{3}{16}$  inch apart. To use, sprinkle the sample across, over a piece of clean paper, and separate that which goes between the troughs from that which catches in them. After putting aside the latter portion, sprinkle across the sampler the former portion, and so

continue until a quantity is obtained about sufficient for assay.

*Sieves.*—A sieve of 80, 90 or 100 meshes to the linear inch is necessary. Such sieves are furnished of 5, 6, 7, 8, 9, 10, 12 and 15 inches diameter (6 to 8 inches is a good size), of copper or brass wire in a wooden frame. Those composed of horse hair are apt to deteriorate. The box-sieve of tinned iron, consisting of a sieve (of 80 to 100 mesh) with tightly fitting bottom to catch all the sifted material, and cover to retain the dust, is a valuable implement.

A 40-mesh sieve is useful for sieving certain chemicals, and two common flour sieves are wanted for bone-ash and granulated lead.

*Zinc Sifting Pans.* Fig. 7.—These will be



FIG. 7.

found convenient, and are better than paper



for sifting over. A pair is necessary, the material sheet zinc. Length in full 31 inches, of body 25 inches, of neck 6 inches, width of body 12 inches, of neck 2 inches, height of rim  $2\frac{3}{4}$  inches, with upper edge turned over heavy iron wire.

*Spatulas and Spoons.*—By a spatula we



FIG. 8.

mean an instrument shaped somewhat like a table-knife (fig. 8), and used for mixing paints, ores, charges, etc. It may be of iron, steel, copper, platinum, silver, ivory, horn, porcelain or glass. A large one of steel or iron (such as painters use), length in full  $10\frac{1}{4}$  inches, blade  $5\frac{1}{4}$  inches long by  $1\frac{1}{8}$  wide, is a very good size for mixing ores and crucible charges. For weighing out ores and mixing scorification charges, a smaller one of steel, length 6 inches, blade  $3\times\frac{1}{2}$  inch is useful.

Two or three horn spoons, with or without handles, are serviceable for various purposes.

#### SCALES AND BALANCES.

Two balances will be sufficient for the ordinary work of the assayer; a small one for weighing fluxes, ores, lead buttons, cupels, etc., and a more delicate one for very accurately weighing the gold and silver beads and gold residues.

*Scales for Pulps and Fluxes.*—Considerable latitude can be allowed in the choice of such scales. Balances can be procured carrying 2, 5, 10, 20 or 30 ounces and upward, and ranging in delicacy from  $\frac{1}{60}$  of a grain to 1 grain. For descriptions, illustrations, and prices of these and others, see the lists of the various manufacturers.

Not wishing to puzzle the student too much, I specify but four:

Fig. 9 represents as satisfactory a pair as can be wanted. It has a spirit level and two thumb-screws, movable scale-pans ( $3\frac{1}{2}$  inch

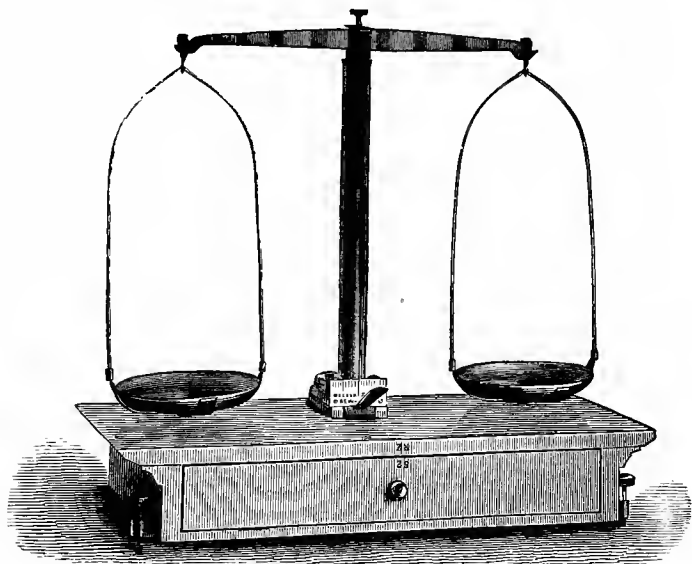


FIG. 9.

diameter), and when it is to be transported, all the parts on the box can be packed in the drawer. Its capacity is 10 oz. (about 311 grammes), and it is sensible to  $\frac{1}{20}$  of a grain (about  $3\frac{1}{4}$  milligrammes). Its cost is \$22.00. (See Becker's list, No. 19.) A glass case in which to keep the scales is a good thing to have, and costs \$6.00.

Troemner makes a similar balance, capaci-

ty 16 oz., sensibility  $\frac{1}{20}$  grain, diameter of pans 4 inches, price \$18.00. (See Troemner's list, analytical scale No. 2, fig. 22.)

A still cheaper but satisfactory balance, similar to the preceding, is likewise furnished by Troemner, capacity 8 oz., sensibility  $\frac{1}{20}$

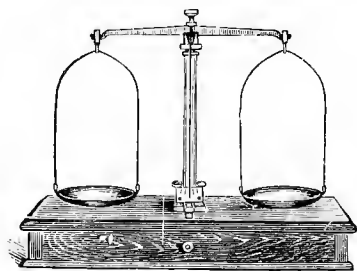


FIG. 10.

grain, diameter of pans  $3\frac{1}{4}$  inches, price \$15.00. It is represented in fig. 10. The objections to it are that it lacks the spirit level and adjusting screws, so that it is not always easy to get it into perfect equilibrium.

No advice need be given for setting up the above, as printed directions usually accompany the scales.

Whatever pair be used, it is advisable to

take two large watch glasses, in diameter a trifle less than that of the scale pans, and file down one or the other till they balance each other perfectly. Weigh all charges in these, thus avoiding any danger of corrosion or attrition of the scale pans.

A soft brush should be employed to brush out the contents of the glasses.

It is a good plan to *always* place the weights in one pan (the right-hand one), and whatever is to be weighed *always* in the other.

In case many crucible assays are to be made (requiring the weighing of many fluxes), a great deal of wear and tear of the balances described can be avoided by substituting

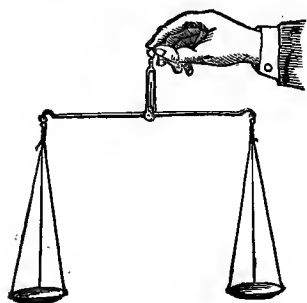


FIG. II.

*hand-scales*, which are cheap and serviceable. They are made with brass beam, from which horn scale-pans are suspended by means of silk threads (fig. II). They can be se-

lected from a dozen sizes, the length of beam ranging between 4 and 12 inches ( $7\frac{1}{2}$  or  $8\frac{1}{2}$  is best—prices \$2.75 and \$3.00). Support them on a nail by the ring at the top, and use them for any and all weighings save those of the ores. Of course no watch-glasses need be used with these scales. Their sensibility is from  $\frac{1}{10}$  to  $\frac{1}{20}$  grain.

Occasionally it becomes necessary to weigh large quantities (pounds) of ores, fluxes, etc. Use whatever scales are easiest obtained; I need not go into detail concerning them.

*Balances for Weighing Gold and Silver Beads.*  
—Here likewise is a range of choice, and personal preference comes largely into play.

When the assayer intends to travel considerably, the balance now spoken of will be the most suitable. Length 9 to  $9\frac{1}{2}$  inches, height  $9\frac{3}{4}$  inches, width from 3 to 4 inches. It packs into a light box, and by means of a strong leathern strap can be carried by the hand. Total weight, boxed, about  $4\frac{1}{2}$  pounds. With the proper weights this balance will weigh

$\frac{1}{10}$  milligramme, and by use of the swinging needle and ivory scale will indicate  $\frac{1}{20}$  milligramme.

It is made both by Becker (No. 2 of his list) and Troemner—the prices, with weights (1 gramme down to  $\frac{1}{10}$  milligramme), being \$75 and \$65 respectively.

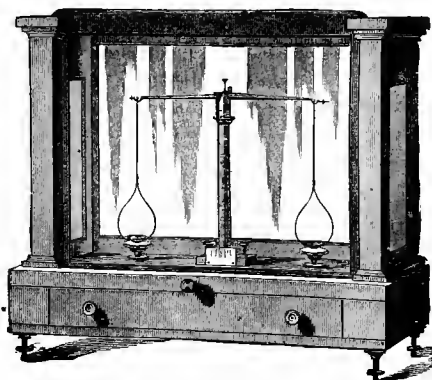


FIG. 12.

When the balance is not liable to be moved around very often, that shown in fig. 12 will serve nicely, and is considerably cheaper. The needle indicates  $\frac{1}{2}$  of a milligramme, and each pan can bear a load of 25 grammes. Price

\$55.00 of either Becker (No. 1) or Troemner (No. 1).

A similar but larger and somewhat more delicate balance is made by Becker (No. 3—price \$78.00). The needle indicates 10 divisions on the scale for 1 milligramme. The greatest objection to all of the preceding balances lies in the fact that they have no graduated beam to carry a rider to show the weight below 10 milligrammes, but instead indicate it by the deviation of a needle. The following possess this advantage:

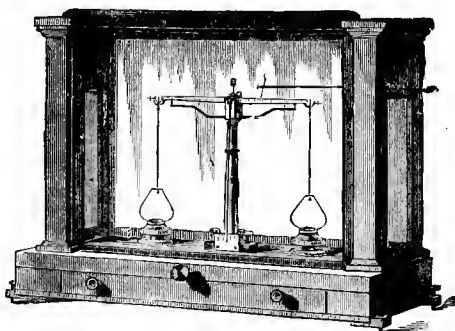


FIG. 13.

Troemner's No. 2 (fig. 13 of this book) is a fine balance. The beam at the right is divided



into *tenths*, each tenth numbered and corresponding to 1 milligramme, and furthermore each tenth is subdivided into tenths, so that by means of the movable rider carried by the rod (seen in the upper right portion of the engraving), a button of  $\frac{1}{10}$  milligramme can easily be weighed. And more; since the spaces between the  $\frac{1}{10}$  milligramme divisions are appreciable, by placing the rider half-way between any two, a weight of  $\frac{1}{20}$  of a milligramme can be determined. Price of this balance, \$80.00.

There is a still larger balance (Becker No. 5, Troemner No. 3—price \$95.00) which is more delicate and better finished than the preceding.

Oertling, of London, furnishes a most exquisitely delicate and accurate balance (No. 12), represented in fig. 14, which is far ahead of any other made. It is expensive (\$200), but where very delicate work is required, as in weighing the gold residues from small quantities of low grade ores, it is indispensable.

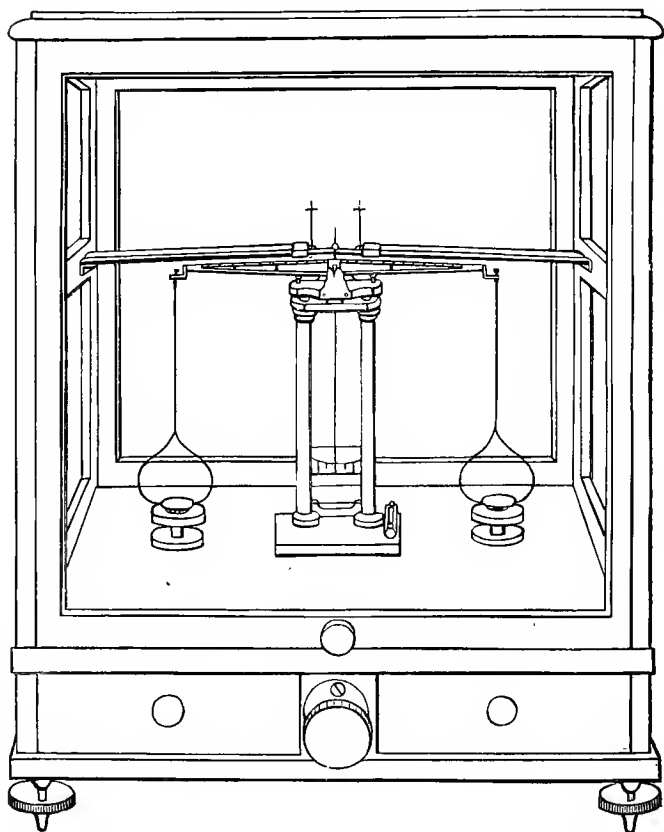


FIG. 14.

See the price-lists of the manufacturers quoted.

*Special Directions.* — It is beyond the province of this book to enter into a study of the philosophy of the balance, and neither do I consider it necessary to give minute and exact details of its various parts. For these consult the larger manuals. (Mitchell, pp. 25–30.)

Nor need I give many directions as to the proper setting up of such balances. Printed directions usually accompany them, as in the case of the less delicate scales.

It must be remembered that *all* of the balances described are *very delicate pieces of apparatus*, and should be guarded with the *utmost* care. They should be placed far from the heat of the furnace and even away from the rays of the sun, tending to unequal expansion and subsequent contraction. Shocks must be avoided and even *continual gentle agitation*, and they should be kept away from *acid fumes* (particularly those of *nitric acid*), and out of moist atmospheres. By having a small vessel filled with *dry fused calcic chloride*

always inside the case of the balance, the moisture present will be absorbed by it, and thus prevent, in a measure, the rusting of the steel parts of the balance. When saturated replenish.

These balances are provided with steel knives and agate bearings, spirit level and set-screws. By means of the latter and by observing the spirit level, the balance can be placed in a state of perfect equilibrium, *and it should always be kept in such.* To ascertain whether it is in adjustment, throw the rest down, thus leaving the pans free, and vibrate the needle by a puff of wind from the hand. The needle should go to the same distance on either side, less a very small fraction due to the decreasing momentum. If it does, the balance is in equilibrium; if it does not, adjust the difference by means of a little screw at one end or the other of the beam, or arrow in the centre.

When not in use, the rest should not be left down, and on the other hand, when using

the balance, it should not be brought up when the needle is vibrating, as this tends to throw the knives off the agate bearings, and so work injury.

With these balances, as with the ore scales, put the weights always in one pan, the material to be weighed in the other. Since the rider in most balances is used on the beam at the right, it is better to employ the right-hand scale-pan for the weights. Do not leave the weights on the pan for too long a time.

A very soft and fine camel's hair brush may be employed to cleanse the scale-pans or other parts from dust.

Finally never use these balances for any other purposes than for weighing gold and silver beads, small pieces of silver or gold, etc.

#### WEIGHTS.

The assayer needs three sets:

1st. A set in the French or metric system, ranging from 50 grammes down to 1 centi-

gramme (10 milligrammes). Since they are not to be used for very accurate work, but only for weighing fluxes, lead buttons, and other comparatively rough purposes, they need not be very expensive (\$5.00 to \$6.00).

2d. A second set of metric weights, to be very accurate, their range from 1 gramme to  $\frac{1}{10}$  milligramme, their use for weighing gold and silver beads. Such a set is included in the price given for the assay balance for gold

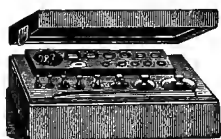


FIG. 15.

and silver beads first mentioned. Separately, they will cost \$8.00 to \$10.00.

Fig. 15 represents a box of these weights.

3d. A set of assay ton weights. These are important, and should be very accurate. Their range is from  $\frac{1}{20}$  to 4 A. T., and price about \$6.00.

These weights are simply invaluable on account of their use requiring no calculations beyond a few multiplications or divisions.

Their connection with ounces, pounds and tons is seen very easily.

There are 29,166 Troy ounces in a ton of 2,000 lbs. There are 29,166 milligrammes in 1 assay ton, therefore 1 milligramme corresponds to 1 ounce. Consequently, if on an assay of  $\frac{1}{5}$  A. T., a bead of 6 milligrammes of gold is obtained, then 1 ton of the ore would contain  $6 \times 5$  or 30 ounces of gold. If on the contrary, the 6 milligrammes of gold came from 4 A. T. of ore, then 1 ton of the ore would produce but  $6 \div 4$  or  $1\frac{1}{2}$  ounces.

Besides the above three sets, it will be found desirable to have a fourth set of grain weights which may range between 1,000 grains and  $\frac{1}{100}$  grain, or 300 grains and  $\frac{1}{10}$  grain. They need not be extremely accurate. The first set will cost \$10 or \$11; the second \$2.00. It is sometimes necessary to weigh a bead, button or other object directly in grains, when these weights will be handy.

For large weighings in pounds, the proper

weights will usually be found to accompany the scales. \*

(See tables of weights in Appendix.)

#### FURNACES.

There are *three* distinct and separate operations to be performed in an assay furnace—roasting, crucible fusion, and muffle work (*i.e.* scorification and cupellation).

In an assay laboratory of any extent, where many assays are daily performed, it will be advantageous, if not imperative, to have a special furnace for each of the above classes of work, but ordinarily the assayer can manage to get along with one. It is requisite, then, that the one selected be adapted to carry on all of the aforementioned operations. As to the particular kind he must consult his individual preference—and his purse. I cannot here describe all the varieties of furnaces

\* If many gold bullion assays are to be made, the assayer will find it extremely convenient to have a set of so-called "gold weights." (See the article "The Assay of Gold Bullion.")



which have from time to time been devised ; all I can do is to speak of a few considered the best.

The heat-supplying medium of a furnace may be any one of three kinds of fuel, which fact, therefore, will serve to form a classification of the furnaces themselves into three divisions :

- A. Furnaces employing gaseous fuel.
- B. Furnaces employing liquid fuel.
- C. Furnaces employing solid fuel.

Strictly speaking, the heat in any case comes from the combustion of a gas, for whether the fuel be liquid or solid, the burning matter is either the liquid transformed into a gas, or it is gas driven off from the solid fuel. But the distinctions drawn will do well enough for my purpose.

*A. Furnaces Employing Gaseous Fuel.*

These are the so-called *gas furnaces*, meaning thereby that the source of heat is our common illuminating gas. But as this fuel will not be on hand for the majority of those

for whom this book is written, I shall not go into any great amount of detail concerning the furnaces which use it. Those who desire to know more about them are referred to Mitchell, pp. 79 to 100, and to the circulars of the Buffalo Dental Manufacturing Company.

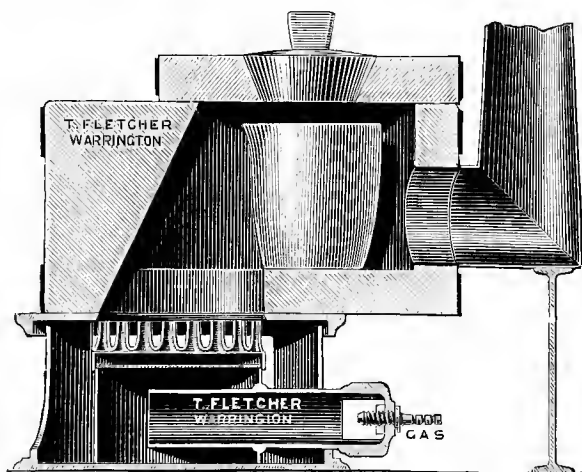


FIG. 16.

The above company manufactures furnaces for either crucible or muffle work, or both, some of which require a blast, others only the natural pressure of the gas.

I cannot refrain, however, from highly praising one of the furnaces made by this company on account of its simplicity and effectiveness. It is represented in section in fig. 16. It is advertised as being intended mainly for crucible fusions, but I have found it to work with perfect success for scorifications and cupellations. A  $2\frac{3}{4}$  inch scorifier is the largest that can be well managed in the smaller sized furnace. By connecting the stove-pipe with a chimney flue, and adding a damper, the draft can be regulated perfectly. Gas supply required, 17 cubic feet per hour;  $\frac{3}{8}$  inch pipe and tap. To operate, turn gas on full and light. In about twenty minutes the furnace is ready for work. For scorification, place the charged scorifier in the furnace and put on the lid. When the lead is melted, slide the lid to one side to admit air, and keep it so till the charge covers over. Proceed in a similar manner for cupellation.

The scorifications proceed rapidly, and the cupellations can be made to do so if desired

(as in the case of lead buttons from gold ores). Indeed, by the proper manipulation of the damper, the supply of gas, and the lid, almost any degree of fusion or oxidation can be obtained.

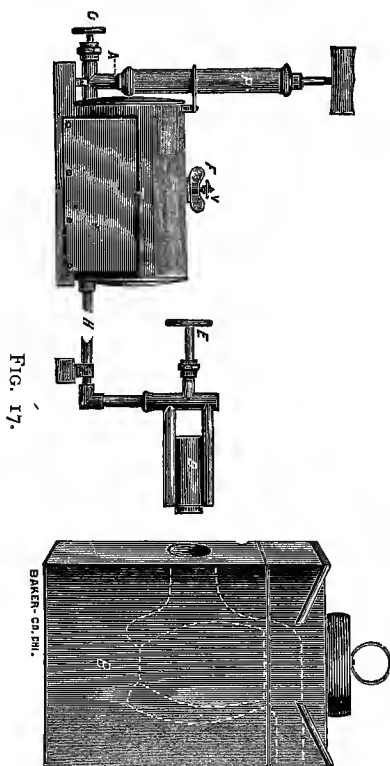
The smaller sized furnace will take a crucible 3 by 2 $\frac{5}{8}$  inches; the larger, one 4 by 3 $\frac{1}{2}$  inches, and will use 22 cubic feet of gas per hour. Prices, \$10 and \$15 respectively.

*B. Furnaces Employing Liquid Fuel.*

There are many varieties of furnaces that come under this heading, their fuel being refined petroleum, gasoline, etc. As with gas furnaces proper, some are intended for crucible fusions, others for muffle work; still others are for both. The air pressure in some forms is derived directly from foot bellows, in others from air compressed by an air-pump.

(Consult the circulars of the Buffalo company already mentioned for descriptions of their furnaces; also Mitchell, pp. 72 to 78.)

Fig. 17 represents Hoskins' Hydro-carbon Assay Furnace. P is an ordinary air-pump,



at the bottom of which (at A) is a valve which closes automatically upon releasing the pressure from the pump. C is a check-valve which closes completely the inlet to the tank T. V

is an air-vent screw for letting off the pressure when through an operation. F is the filling screw. H is the pipe leading from the tank to the burner D. E is the burner-regulator, terminating in a fine point, closing the orifice of burner. B is a fire-brick crucible furnace. (A muffle furnace is also supplied.) The crucible furnace will hold a crucible  $4\frac{1}{2}$  inches high by  $3\frac{1}{2}$  inches across the top. The muffle furnace will carry a muffle 7 inches long by  $3\frac{1}{2}$  wide, or one 7 inches long by 5 wide, according to size. Total weight of apparatus packed, about 65 pounds.

The fuel is gasoline—that of  $74^{\circ}$  is best—one gallon will burn from six to seven hours.

To operate, close E; unscrew F and introduce about two quarts of fluid. Replace F and close V; open C one or two turns, give two or three strokes to pump and close C. Heat the burner D by burning a little gasoline under it (an old scorifier will do to hold the gasoline); when hot enough apply

a match and open E gradually until its action is uniform. By the use of the pump as above, the blast can be made of the intensity desired. To stop its action, shut regulator E or open screw V, or both. When not in use, the vent V should invariably be left open. The mouth of the burner D should be from two to five inches from inlet of the furnace. When putting together, screw all joints up tightly and in position. For very high temperature proceed as follows:

*First.*—Light burner as above and heat the inside of furnace (crucible or muffle) to redness, at least.

*Second.*—Place the burner *close* to the inlet of furnace.

*Third.*—Turn out burner with E, and immediately turn it on again without lighting it, when, if the furnace is hot enough the gas will ignite *inside* of furnace.

Figs. 18 and 19 are representations of Myers' "Jewel" assay apparatus. The first illustration shows it as it is arranged for

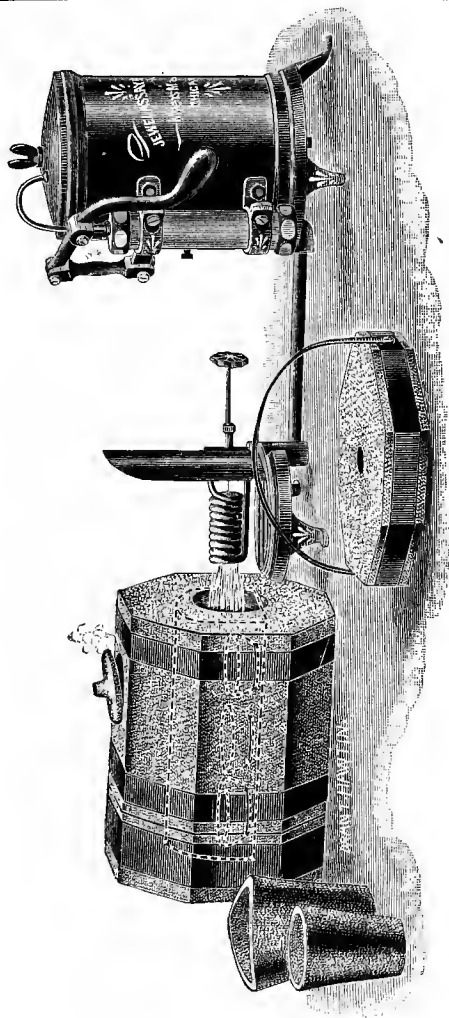


FIG. 18.



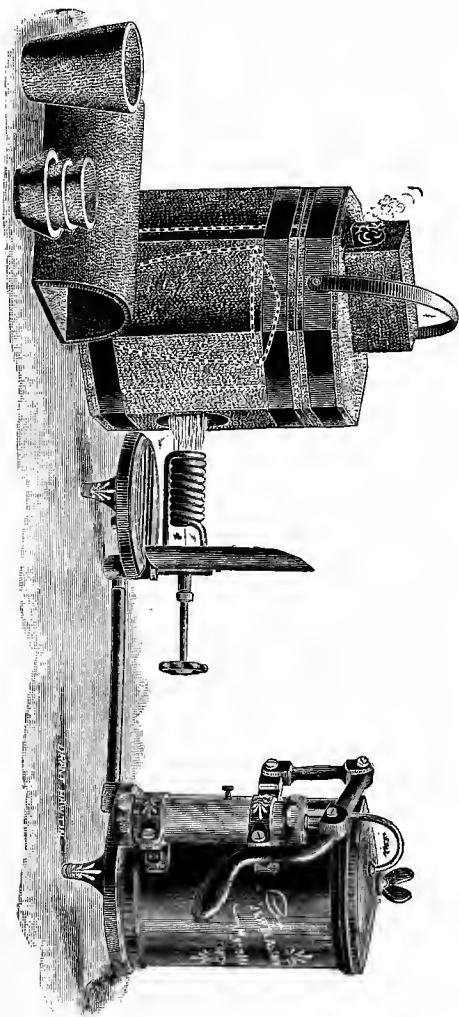


FIG. 19.

scorification and cupellation work in the muffle, the second for crucible fusions. The manner of placing the various parts of the furnace for either kind of work, is shown sufficiently well by the engravings.

Directions for operating, whether for muffle assays or crucible fusions. Unscrew the plug on the top of the reservoir, pour in one half gallon of 74° gasoline, return plug to place and screw it down very tightly. Now open the air-cock shown at the side of the pump cylinder, and pump from twenty-five to thirty times, the more the better, then close the air-cock. Open the needle-valve slightly and allow the gasoline to flow out into the receptacle below the coil, till about half full, when the valve is to be closed.

Ignite the gasoline in the receptacle, and when nearly burned away, open the needle-valve a trifle, letting out a fine stream of gasoline from the reservoir, which at once ignites. The coil has by this time become well heated, vaporizing the gasoline as fast

as it issues, and throwing a burning jet into the opening of the furnace.

Pump some fifty times, and thereafter at intervals of five minutes or so, give a few extra strokes.

The management of the furnace and blast is easily learned after a few trials.

*C. Furnaces Employing Solid Fuel.*—In this class are found the best known furnaces, using as fuel, wood, charcoal, coke, hard and soft coal, or mixtures of them.

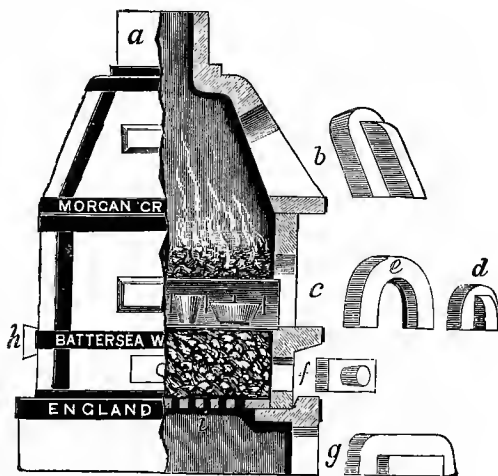


FIG. 20.

The *Battersea* furnace is of fire clay, made

in sections and bound with iron bands. Fig. 20 is a sectional view of the muffle furnace, of which the following sizes are obtainable in this country:

No.	Height, inches.	Diameter, inches.	Sizes of Muffles, in inches.				Price.
C	27	14½	9 long,	3⅝ high,	5½ wide		\$25 00
D	28½	15½	10 "	4 "	6 "		30 00
E	29½	16¼	12 "	4 "	6 "		35 00
F	30	17½	14 "	5 "	8 "		40 00
K	48	23	15 "	6 "	9 "		80 00

*Judson's* Sectional Assay Furnace (patented) is represented in fig. 21. Two sizes are specified. Dimensions in inches :

No.	High.	Wide.	Deep.	Muffle			
				Long.	Wide.	High.	
1	36	18	13	12	6	4	(Battersea J)
2	42	22	16	15	9	6	(Battersea L)

No. 1 is made of part steel and part iron (weight about 300 pounds, price \$45), or all steel (weight 250 pounds, price \$52). No. 2 is manufactured both entirely of cast iron, and part iron and part steel (the latter weighs about 450 pounds, price \$60).

For details concerning the preceding three kinds of furnaces consult the various catalogues and circulars.

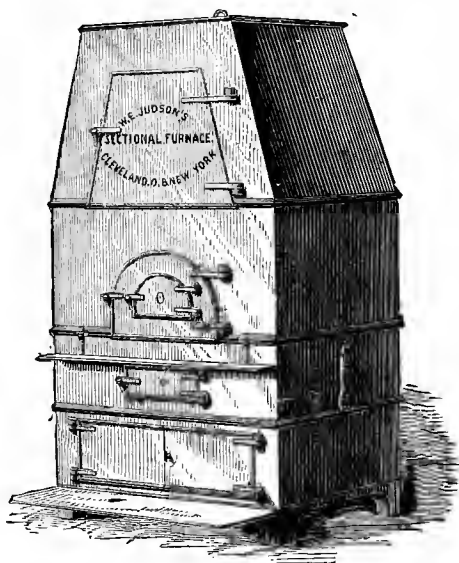


FIG. 21.

*Brown's Portable Assay Furnace.* Fig. 22. —This furnace consists of a sheet-iron frame 27 inches high and 14 inches square, lined with fire-brick in sections, the interior being smooth and straight from top to bottom. The cover is cast-iron, and is *ridged* to lessen the danger of cracking. The muffle door is cast-iron, and is fitted with a circular opening, filled with *mica*, that the operations going

on within the muffle may be seen when the door is closed. The draft-doors are also of cast-iron, and are provided with wheel open-

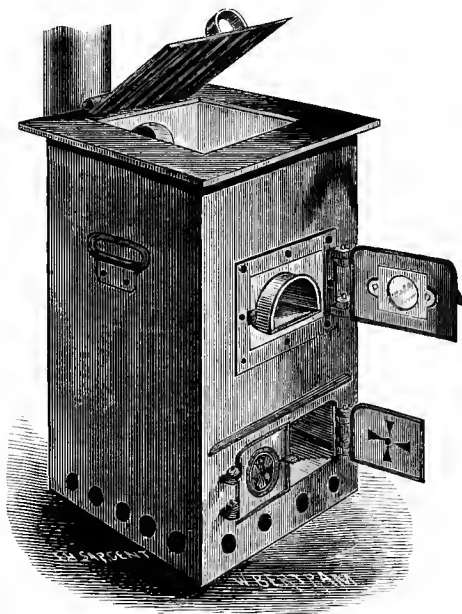


FIG. 22.

ings to further regulate the draft. The circular holes at bottom are in all four sides of the furnace, and serve to keep cool the true bottom of the furnace upon which the ashes fall.

The muffle seen in the opening rests equally upon the fire-brick in front and in the rear of the furnace, leaving a space of  $\frac{1}{2}$  inch between the end of the muffle and the brick to allow the passage of fumes.

The grate is formed of cast-iron bars, 10 inches long, 1 inch square, 6 in number, resting upon a cast-iron frame.

The space below the true bottom is to be filled with fire-brick or sand or other material convenient.

The chimney hole is 5 inches in diameter, thus accommodating a stove-pipe of same dimensions. The bottom of this hole is 17 inches from the true bottom of the furnace, and 8 inches from the bottom level of the muffle.

There is a handle upon each side of the furnace to allow more convenient handling.

The furnace can take either H or J muffle of the Battersea pattern,

Size H.	Length, 10 $\frac{1}{2}$ in.	Width, 5 $\frac{1}{4}$ in.	Height, 3 $\frac{7}{8}$ in.
" J.	" 12 "	" 6 "	" 4 "

but is best adapted for size J, the most commonly used muffle. Entire weight of furnace boxed is 125 pounds.

The above furnace possesses the following advantages :

1st. Simplicity. Having no complicated parts to get out of order.

2d. Usefulness. It can be used both for muffle work and for crucible operations.

3d. Capacity. There is no other furnace manufactured of similar dimensions and weight which can accommodate so large muffles, and consequently produce so much work and so rapidly.

4th. Durability. Being made of heavy sheet-iron, it cannot be broken by handling nor injured by heating.

5th. Adaptability. Any fuel may be employed for which the draft of the chimney is sufficient.

6th. Light weight. Boxed, this furnace weighs but 125 pounds, as against 250 to 400 pounds of other furnaces.



7th. Cheapness. This furnace is from one-third to two-thirds cheaper than any other furnace that will do as good work. Boxed for transportation, \$20.

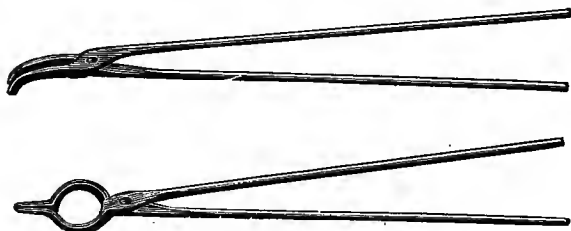
For permanent furnaces of brick, etc., whether to be used for roasting, fusion, scori-fication and cupellation work, see Ricketts. pp. 21-26, and Mitchell pp. 57, 63, etc. The various stamp mills, smelting and sampling works, and mining corporations scattered throughout the West, have usually permanent furnaces burning coke, charcoal, soft or hard coal, which may profitably be imitated.

Furthermore, many a peripatetic assayer has conjured up a temporary furnace of clay, adobe, or home-made bricks, using a tile or large crucible for a muffle, to meet an emergency, and when its days of usefulness were over, left it to decay and ruin. On such occasions, necessity is indeed the mother of invention.

#### FURNACE TOOLS.

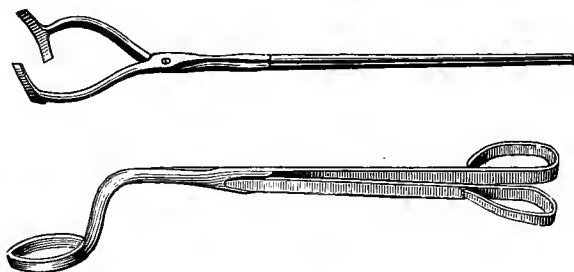
*Crucible Tongs.*—For placing in, and re-

moving from, the furnace, crucibles. The assayer will need one large and strong pair, of wrought iron, 24 to 36 inches long, the grip-



FIGS. 23 and 24.

ping ends of which may be curved or straight, like figs. 23 and 24, or tongs can be procured



FIGS. 25 and 26.

of either one of the two forms given in figs. 25 and 26. Either one, however, of the two first mentioned, will do very well.

A smaller pair, from 15 to 18 inches in length, for lifting small crucibles and large scorifiers, for placing lead buttons in the cups, and for opening and shutting the doors of the furnace, is invaluable (fig. 27).

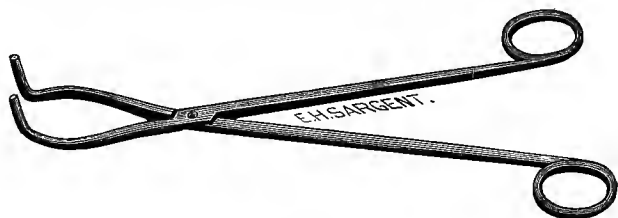


FIG. 27.

A still smaller pair of 8 inches in length (fig. 28), for managing the doors of the furnace, is handy, but not absolutely necessary.



FIG. 28.

*Scorifier Tongs.*—The correct shape is here given (fig. 29). The length about 24 inches.



FIG. 29.

The curved arms fit the bottom of the scorifier, the long arm extending across the top.

The best material for these tongs is steel, and they should not possess too much spring. Two or three sizes should be procured, to accommodate the various sizes of scorifiers.

Fig. 30 represents Judson's patent steel scorification tongs arranged for lifting scorifiers from the rear of a muffle without disturbing those in front.

*Cupel Tongs.*—Several forms are permissible. A common pattern is shown in fig. 31. In using these particular tongs, care should be taken to secure a firm grasp of the cupel, lest it slip through the tongs and be broken, and the bead be lost. On the other hand, too much pressure may crush the cupel.

With these tongs the grip should be made nearer the top than the bottom of the cupel, for should the operator happen to grasp with it a cupel *below* the latter's centre of



FIG. 30

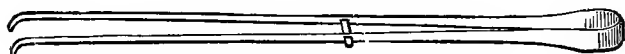


FIG. 31.

gravity (especially when the cupel is soaked with litharge), it will probably turn over, again giving a chance for loss of the bead of precious metals.

The form next figured (fig. 32) is not



FIG. 32.

likely to cause the above accident, nor quite so liable to crush the cupel, and fig. 33 illustrates a better pair than either of the preceding.



FIG. 33.

Fig. 34 represents Judson's patent cupel tongs.

Whatever pair of tongs is used should be of steel or wrought iron, light weight with not too strong a spring, length from 18 to 24 inches, and with a strong guide.

For considerable of my work I have used, instead of tongs, the cupel shovel (fig. 35), and cupel rake (fig. 36). The curve of the latter fits the cupel. By means of these two implements, one or two cupels can be easily and quickly run in or out of the muffle without danger of damage. They can be of light weight wrought iron, and about 24 inches long. For carrying a half dozen cupels at a time, a second shovel with the blade six to eight inches long would be serviceable.

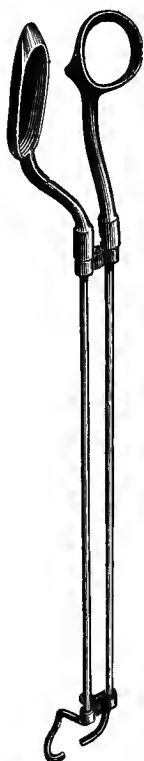


FIG. 34.



FIG. 35.

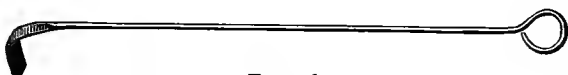


FIG. 36.

*Scorifier or Scorification Moulds, Slag Moulds, or Pouring Plates.*—Two forms are here presented. Fig. 37 is of cast iron and has nine holes; the same is furnished with but six. Fig. 38 is also of iron, and has the advantage of collecting the lead better together, and the disadvantage of having but three receptacles.

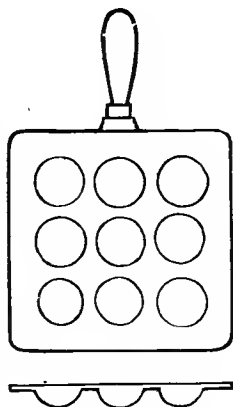


FIG. 37.



FIG. 38.

Any hardware merchant can provide a very good substitute for either of the above

in the shape of a so-called "*gem-plate*," generally with twelve cavities.

Similar moulds can be procured of heavy copper, which has the advantage of not suddenly chilling the slag and thus causing it to retain small pellets of the lead, but they are quite expensive, and if the iron plates are warmed before using, they will serve quite as well.

I do not recommend the practice of painting the interiors of the cups with ruddle or chalk washes.

The utility of scorification moulds is obvious; by employing them the time of cooling is greatly diminished, and the scorifiers can (but they had better not) be re-used.

Large moulds for receiving fused crucible charges can be procured (for example a plumber's lead pot), but as mentioned elsewhere, unless crucibles are rare, they are not necessary. It is the custom in some assay offices to pour a crucible fusion into one of the cavities of the scorification mould



with conical cups (fig. 38). The lead button sinks to the bottom of the mould and the excess of slag, fused salt, etc., runs over the top and into any convenient receptacle.

*Muffle Scraper.*—Shown in fig. 39. Made



FIG. 39.

of wrought iron, length 24 inches. The cupel shovel spoken of can be used for conveying sand or bone ash into the muffle whenever lead has been spilled upon its floor, and the scraper employed for bringing out the pasty mass formed, and smoothing down the surface of the floor of the muffle.

*Pokers.*—One long straight one, 32–36 inches, of  $\frac{3}{8}$  inch wrought iron (fig. 40), a



FIG. 40.

short one, 18 inches, with end bent, for muffle work, and a third ordinary poker, for stirring the fire, are desirable.

## APPARATUS USED IN THE FURNACE.

*Muffles.*—The term muffle is applied to that piece of apparatus figured here in various forms, in which are performed the operations of roasting, scorification, cupellation, etc. Muffles are made of iron, plumbago, or a refractory mixture (*i.e.* sand and fire-clay), most generally the latter. They can be procured in the market in almost every conceivable size (the price lists enumerating some fifty), besides which they can be made to order of any special dimensions.

The air-apertures are in the sides in some (fig. 41), in the end as a single opening (not shown in the cut) in the form most favored in this country (fig. 42).



FIG. 41.



FIG. 42.

Still other muffles are open entirely at both ends, so that their contents can be manipulated as well from the back as from the front. Any muffle can be easily con-

verted into this form by sawing off the closed end.

The size of the muffle employed will be determined by the size and make of the furnace.

In case the furnace is so constructed that the muffle can easily be taken out (and it is well to have it out during the firing up and first heating), then to avoid danger of cracking it by sudden heat it is best to place it on top of the furnace to warm it somewhat before putting it in position.

False floors to the muffle are obtainable, and save the real floor from injury due to spilled lead, etc. They are made of same material as the muffles.

*Crucibles.*—These vessels are made of various materials: black lead (graphite or plumbago), French clay, Hessian sand, charcoal-lined (*i.e.* Hessian sand crucibles with a lining of charcoal and molasses), quick lime, a mixture of magnesia and chloride of magnesium, alumina, and finally those for very special purposes, of porcelain, iron, platinum, gold or

silver. It is but few of these varieties that are needed for the assaying of gold, silver, copper and lead ores, and these I now specify.



FIG. 43.

The so-called clay or sand crucibles are the ones fitted for the assaying of the ores of the four metals named. They occur in two forms, round and triangular (figs. 43 and 44), with covers to match. Almost any size can be obtained



FIG. 44.

from some one of the manufacturers. In giving the charges for crucible work I have generally indicated the sizes of crucibles needed. The most commonly used crucibles will range between  $3\frac{1}{4}$  and  $4\frac{1}{2}$  inches in height, and between  $2\frac{7}{8}$  and  $4\frac{1}{8}$  inches across. For an ordinary crucible charge of one assay ton and fluxes, a crucible  $4\frac{1}{2}$  inches high by  $4\frac{1}{8}$  across will be about right.



FIG. 45.

Fig. 45 shows the form of the French clay or Beaufay crucible or "fluxing pot,"

For muffle lead the specially shaped crucibles figured here (fig. 46) are desirable. The largest size can also be used for fusions of gold and silver ores in muffle. They are made



in three sizes. Those furnished by the Battersea company are known as the "Colorado" crucibles. Those manufactured by the Denver Fire

FIG. 46.

Clay Co. are known as 5, 10 and 20 gramme crucibles. The sizes are as follows; dimensions approximate :

AA, "Colorado" of Battersea Co. or 5 gramme of Denver Fire Clay Co.,  $2\frac{1}{4}$  inches high;  $2\frac{1}{4}$  inches across.

A, "Colorado" of Battersea Co. or 10 gramme of Denver Fire Clay Co., 3 inches high;  $2\frac{3}{4}$  inches across.

B, "Colorado" of Battersea Co. or 20 gramme of Denver Fire Clay Co.,  $3\frac{1}{2}$  inches high; 3 inches across.

*Roasting Dishes.*—These are made of refractory clay or black lead, of the form indicated (fig. 47). They should be quite shallow. They are used for



FIG. 47.

the roasting of ores containing much antimony, arsenic, sulphur and zinc. They are furnished in sizes ranging from  $1\frac{3}{4}$

to 8 inches in diameter. The 3-inch dish is suitable for roasting  $\frac{1}{5}$  A. T. The 5 and 6 inch sizes can be employed with satisfaction for open air roastings of 1, 2 or more A. T. (for crucible work), in place of the frying-pan.

*Scorifiers.*—These articles are made of a material similar to that of the clay roasting dishes. Fig. 48 shows the right shape. They should be somewhat shallow; in texture uniform, and free from cracks and holes.



FIG. 48.

They can be procured in sizes varying from 1 inch to 5 inches in diameter.

The best size for all ordinary scorifications is the  $2\frac{3}{4}$  inch (if the muffle is wide enough to admit it). This size takes from  $\frac{1}{5}$  to  $\frac{1}{2}$  A. T. of ore, according to its gravity. The  $2\frac{1}{4}$  inch is well adapted for re-scorifications, that is, for reducing in size too large lead buttons. It can also be employed when very little of the ore is to be worked, say  $\frac{1}{10}$  A. T.

Have the  $2\frac{3}{4}$  inch in large quantity, with one half as many  $2\frac{1}{4}$  inch and perhaps a few

$2\frac{1}{2}$  inch. For certain other purposes it is advisable to have on hand a few of the 3 and  $3\frac{1}{2}$  inch sizes.

As the manufactured scorifiers will stand a great deal of rough handling without injury, and since they are well made and cheap, it is better to purchase them, rather than to attempt their home manufacture which is not a very easy thing.

*Cupels.*—Among the most useful articles the assayer possesses. They are employed to absorb oxides of almost all the metals save those of gold and silver, thus leaving these two metals behind in a state of comparative purity. Lead is the metal whose oxide, litharge, they absorb in great quantity. Any substance which will absorb these various oxides would do, but for many reasons, burnt bones or bone-ash is preferred. Good bone-ash is so easily and cheaply obtained that it seems a waste of time to more than indicate the process whereby the assayer himself may make his own supply. In brief, horse or

sheep bones are boiled repeatedly in water, their organic matter (grease, carbon, etc.) burnt away, they are then finely ground, sifted and washed. (Mitchell, pp. 133-4.)

Very good cupels can be purchased in several sizes, and *when* they are good, can be safely packed and transported.

The one chief objection to purchased cupels is their expense, therefore ordinarily it is cheaper to make them, to do which I now give directions:

The bone-ash which can be obtained in bulk and of several grades, is mixed, say one pound at a time, with a strong solution of pearl-ash (or carbonate of potash) in warm water, till the mixture adheres well together, though it must not be at all pasty. (The right degree of moisture is hard to describe but easy to acquire.) When a portion of the mixture is squeezed in the hand, it should cake together (somewhat like half-melted snow) and show the imprint of the fingers. Now sift through a common flour sieve, place



the cupel ring upon a block of wood (having a large piece of brown paper spread out below all), fill about flush with the surface with the sifted bone-ash and strike the plunger into the ring four or five times moderately heavily. Turn the plunger around in the ring once or twice and push the cupel gently out. A little practice will soon enable the assayer to turn out perfect cupels.

The moisture remaining in the cupels can be driven out by placing them on the top of the furnace after a day's running, or, what is better, by allowing them to dry in the normal atmosphere of the room or by exposure to the sunlight. Cupels thus slowly dried are less likely to crack on using.

The texture of the cupel, that is, its degree of porosity, depending on the fineness of the bone-ash and amount of compression, is quite important. If too fine bone-ash is used, the cupel will crack (or "check," as it is sometimes termed), in the muffle; if too coarse, the cupel will absorb silver, causing loss.

Therefore a medium grade had best be chosen. The above two difficulties are in a measure obviated by making the body of the cupel, that is, the lower two-thirds, of coarse material, and the upper third of fine.

If the cupel is too compact, cupellation proceeds too slowly ; if too loose or porous, the cupellation proceeds too rapidly, causing a certain absorption of silver with the lead. As in everything else, experience is the best teacher.

The *form* of the cupel is immaterial. Fig.



49 represents the one which I prefer on account of the ease with which it can be removed from the mould.

A cupel with diameter of  $1\frac{1}{2}$  inch is a convenient size.

*Annealing Cups.*—Shown in fig. 50. Used



in the assay of gold bullion. Should be well made, light but strong. Various sizes can be obtained.

*Annealing Plate.*—Employed for annealing a number of slips at once, in the gold bullion assay. In size about 6 inches long, 2 wide

and  $\frac{3}{4}$  inch thick. May be made of an old muffle floor rubbed down. Can be purchased of either fire clay or plumbago.

#### APPARATUS OF GLASS AND PORCELAIN.

*Sample Bottles.*—A number of these, of two, four, six and eight ounce capacity, with wide mouths and cork stoppers, are desirable for pulverized samples of ores.

*Re-agent Bottles.*—The dry re-agents are best kept in wide-mouthed bottles (known as "salt mouths"), glass-stoppered, thus preventing the admission of dust and moisture.

Stone-ware crocks of various sizes can be employed instead of the bottles, and will, of course, contain greater quantities.

Fruit-jars with threaded necks and metallic caps will stand transportation better than the bottles, and tin cans or wooden boxes will pack more closely and last longer than either. Circumstances will alter cases if the laboratory is to be more of a traveling than a fixed one.

Whatever receptacles are used, they should be properly labelled.

Bottles, of course, are necessary for the wet re-agents. The distilled water can be preserved in *clean* demijohns enclosed in wicker-work, or in clean stone jugs.

*Wash Bottle.* Fig. 51.—To contain distilled or pure water. A quart is the best size. By blowing in at the opening *a*, a fine stream of water is thrown out through *b*.



FIG. 51.

*Watch Glasses.* Fig. 52.—More correctly known as clock-glasses. A pair is desirable



FIG 52.

to place in the scale pans of the ore scales, to keep injurious substances away from contact; in diameter they should be slightly less than that of the pans.

*Porcelain Capsules or Crucibles.*—For hold-



FIG. 53.

ing the bead of gold and silver while being parted. Two sizes are convenient, one being 1 inch in diameter across

top by  $\frac{3}{4}$  inch in depth, the other  $1\frac{1}{4}$  inch diameter by  $1\frac{1}{16}$  deep. A good shape is that here figured. A dozen of each size will last some time.

*Test Tubes.*—Used in qualitative tests. It is well to have some of four, six and eight inches in length. A rack to hold them is convenient. Some assayers employ them for parting gold and silver beads.

*Parting Flasks (or Boiling Flasks).*—A



FIG. 54.

small flask, capacity  $\frac{1}{2}$  ounce, of form as figured, is sometimes used for parting gold and silver beads, instead of

test-tubes or porcelain capsules. At least three will be needed. Round-bottomed flasks are also frequently used.

*Matrasses.*—Flasks of the shape delineated



FIG. 55.

in fig. 55 and used for the parting of gold bullion, are generally termed matrasses. It is quite important for the purposes of manipulation that the neck

of the flask should fit snugly into the annealing cups employed. Can be held by a wooden clamp.

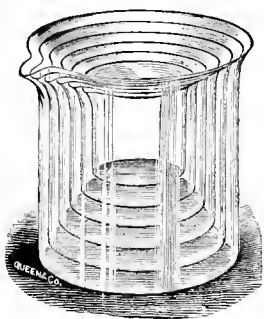


FIG. 56.

*Glass Beakers.*— Will be needed in the copper and other analyses, chlorination and other tests, etc. They should be lipped (fig. 56), and preferably of thin material to stand heat. Several nests may be wanted.



FIG. 57.

*Glass Funnels.*—For analyses of different kinds. Should be of an angle of  $60^\circ$  (fig. 57).

*Glass Stirring Rods.*—Very useful. Cut up a long glass rod into various lengths, and round each end by holding in a lamp or gas flame for a minute or so.

*Flasks.*—One will be wanted for the chlorination assay of gold. Several sizes can be made use of, for wash-bottles, to retain solutions for any length of time, etc. Should be of thin glass.

*Separatory Funnel.*—See “Chlorination Assay for Gold,” in appendix.

*Casserole.* Fig. 58.—Of porcelain. Can be put to many uses, as small evaporations, etc.



FIG. 58.

*Pipettes.* Fig. 59.—A 10 c.c. and a 5 c.c.



Fig. 59.

will be required in the copper analysis. They can be home-made by drawing down to a fine opening one end of a glass tube, and rounding the other.

*Mortars and Pestles.*—Small sizes of these are useful in pulverizing re-agents, etc. Their material may be either glass (fig. 60) or porcelain; shape as represented.



FIG. 60.

#### MISCELLANEOUS APPARATUS.

*Note-books.*—Indispensable. Nothing should be left to the memory, but everything important relating to the assay of an ore should be down in black and white.

The number of the ore, its character, the charge for the furnace, conduct in the fire, results of the various operations, as shown by the crucibles, scorifiers, cupels, slags, buttons, beads, etc., and all calculations, should be taken note of.

*Gummed Labels.*—An assortment of various shapes and sizes will be found extremely convenient.

*Boxes.*—Of pasteboard,  $5\frac{1}{2}$  inches long,  $3\frac{1}{2}$  wide and 2 high, to be used for pulverized samples. Paper boxes, tin boxes, paper bags and cloth bags are also used.

*Paper.*—Sheets of heavy brown or manilla paper for the mixing of ore samples are necessary.

Sheets of black glazed paper can be used instead, but it is better to reserve these for the mixing of charges, as they are a little too delicate for rough work. Some assayers use pieces of sheet rubber, rubber cloth or oil-cloth.

Whatever kind be employed, see that it



has no holes to allow loss of sample or charge.

Tissue paper for wrapping up borax glass into pellets, and for enfolding minute gold and silver beads for flattening, will be needed. Filter-paper is indispensable for filtrations; also valuable for removing small quantities of moisture from the interiors of the porcelain capsules in the operation of parting. Clean blotting-paper will do for the latter purpose.

The filter-paper may be obtained in sheets or cut round of any size wanted.

*Brushes.*—Several are necessary. First, in case the rubbing-plate is employed, a large brush such as is used by painters is invaluable.

For brushing charges from the scale-pans or glazed paper, a medium size camel's hair is wanted, and for brushing the scale-pans of the delicate balances a very fine camel's hair brush is needed.

*Pincers.*—A few pairs of varying sizes are handy. One of about 8 inches in length,

strongly made of wrought-iron, a 4-inch pair of brass, and a third pair with limbs running down to a fine point, for picking up minute gold and silver beads, will suffice.

*Hammers.*—While the assayer can get along



FIG. 61.

with one or two hammers, it is better to be provided with four or five. A heavy 5-pound sledge-hammer, a couple of smaller ones of about two pounds, one of them having one sharp edge and a square face (fig. 61), the other with both faces blunt, a small hammer for breaking crucibles and scorifiers and flattening buttons, and a  $\frac{1}{2}$  ounce sharp-edged hammer for trimming small specimens and flattening gold and silver beads, are very convenient.

A sharp hatchet for kindling-wood and a

dull one for breaking coke complete the category.

*Anvils.*—A miniature blacksmith's anvil (fig. 62), weighing 10 pounds, and properly

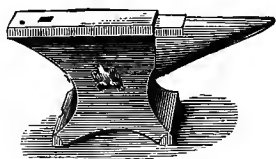


FIG. 62.

mounted on a block, will be in constant demand. A simple yet satisfactory method of mounting the anvil has been of long-time use in my laboratory. An oaken block, 30 inches high by 12 inches through in both the other directions, has a frame of 1 inch wood screwed to its sides at the top, rising one inch above the surface. On the top of the block is nailed a half inch thickness of rubber belting, leaving one-half inch space between its surface and the upper edge of the surrounding frame. The anvil is screwed down to a piece of 2-inch oak fitting this space. The oaken block furnishes a firm

support for the anvil, the rubber deadens the sound of blows, and by lifting off and putting aside the anvil and its bottom, the block serves as a convenient table for breaking ores in the mortars.

A flat plate of steel,  $1\frac{5}{8}$  by  $1\frac{1}{4}$  inches and  $\frac{1}{2}$  inch thick, on which are to be flattened the gold and silver beads, is useful.

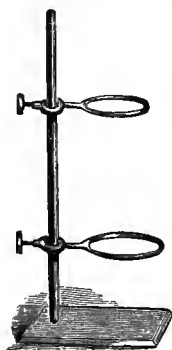


FIG. 63.

*Ring-stand.*— This implement, made of cast-iron, is useful for many purposes; to hold a wire triangle that supports the porcelain capsule used in parting, to support a sand-bath, wire-gauze, etc. Fig. 63 shows one pattern.



FIG. 64.

*Wire Triangle.*— Of twisted wire (best of platinum), in shape as figured, for supporting capsules, etc. It may also be strung through pieces of pipe stems.

*Sand-baths.*—Any flat plates of tin or iron filled with sand. Their use is to distribute the heat around any vessels imbedded in the sand.

*Wire-gauze.*—Three-inch squares of iron wire gauze are used for same purposes as the sand-baths.

*Burners, Lamps and Stoves.*—When gas can be procured, the Bunsen burner, fig. 65, is the best supplier of heat for small purposes. By turning the ring at the bottom so as to close the holes, a light-giving flame is produced; by leaving the holes open, there is obtained a heating flame due to the more perfect combustion. A large alcohol lamp is the best substitute for the Bunsen burner.



FIG. 65.

Stoves for burning gas, gasoline, kerosene, etc., etc., I leave for individual selection.

*Frying Pan.*—Aside from any culinary importance, this kitchen utensil serves a useful end in receiving melted borax glass;

spreading the latter out that it may cool in a thin sheet.

It is also occasionally employed in the roasting of sulphurets, etc., on a comparatively large scale.

In either case coat the pan with chalk or ruddle paint.

*Blowpipe*.—For testing minerals and for fusing gold and silver together. There are many forms of this important little instrument, but a plain curved one is as satisfactory as any for ordinary blow-piping. (Consult the works on Blowpipe Analysis.)

*Cupel Moulds*.—For making cupels. These are made of either steel or brass, but preferably of the latter, since they do not rust so quickly. A mould generally consists of three parts, the plunger or pestle, which is convex at the bottom to form the concavity of the cupel, the ring into which the plunger partly or wholly slips, and a bottom plate upon which the ring rests. In some moulds this bottom plate is circular and fits into the ring.

Fig. 66 represents a good form, which is of brass, and is furnished in sizes that make cupels of  $1\frac{1}{4}$  and  $1\frac{1}{2}$  inches diameter. It has no bottom plate, but a smooth block of hard wood will serve equally well. The cupel this mould furnishes has its sides at right angles to the base (see fig. 49). One advantage this form of mould possesses is that by



FIG. 66.

using more or less bone-ash, cupels of varying thicknesses can be obtained by reason of the plunger sliding *in* the ring, which is not the case with all others.

A special machine has been devised for making cupels, but I am not at all certain that it turns them out any better than does the common mould, nor more rapidly. If greater pressure is needed than that given by the hammer or mallet, a second-hand letter press might be utilized, by knocking off the upper plate and making a few alterations.

*Shears.*—For cutting gold and silver bullion, sheet silver, lead-foil, etc. Should be

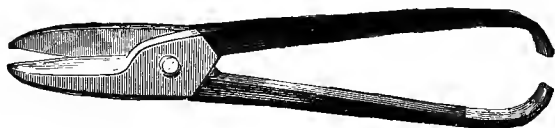


FIG. 67.

strong and have a keen cutting edge. Fig. 67 represents a good form.

*Scissors* for cutting filter papers, etc., will be wanted.

*Rolls* for thinning out gold and silver bullion are more needed in a mint than elsewhere.

*Magnifying Glass.*—Pocket size very useful.

*Magnet.*—A small pocket magnet will come in play very often both in the field and laboratory. Metallic iron, magnetic oxide of iron, nickel and cobalt are attracted by it.

*Ingot Moulds* for gold, silver and lead can be obtained in twenty or more sizes.

*Steel Alphabets and Figures.*—The bullion assayer will need these for stamping bullion.



They should comprise the numerals from 0 to 9, an alphabet, and certain stamps in one piece, as "Gold," "Silver," "Fine," "Value," "Total," "No.," "Oz." and "\$." In size the above may vary from  $\frac{1}{32}$  inch to  $\frac{5}{8}$  inch. Steel dies with name of mine, company, assayer, etc., can be procured as desired.

*Cold Chisels.*—One large (1 inch diameter) and one small one ( $\frac{1}{2}$  inch) are useful.

*Miners' Gold-washing Pans.*—See "Pan Test for Gold," in appendix.

*Filter Stands.* Fig. 68.—For holding funnels. Wooden ones are easily obtained or made.

*Battery, Platinum Vessels, etc.*—See "Copper Analysis."

*Amalgamation Mortar* or laboratory "arrastre."—It is of cast iron, and is simply a mortar with its pestle revolving on a spindle. There are other forms procurable. See "Amalgamation Assay," in appendix

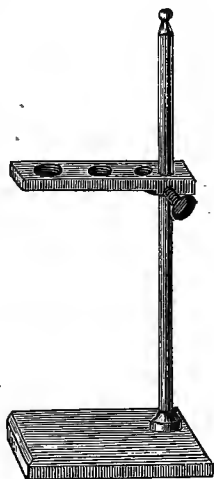


FIG. 68.

*Iron Retorts.*—They are used for distilling off the mercury from an amalgam. Can be found in sizes ranging from  $\frac{1}{2}$  to 24 pints. The smallest size will do for ordinary work.

*Chamois Skin* or any other fine leather.  
—Used in squeezing out the free mercury from an amalgam.

## CHAPTER II.

### RE-AGENTS USED IN ASSAYING.

UNDER this heading I purpose to speak of those re-agents (or substances which react), necessary for the assaying of gold, silver, copper and lead ores. I shall tell what they are, how they act, when to be used and with what object, and, finally, how to prepare them when preparation is necessary.

#### DRY RE-AGENTS FOR ASSAYING.

The *dry* re-agents needed for the assays described in this book are sixteen in number, as follows :

1. Bi-carbonate of soda.
2. Carbonate of potash.
3. Cyanide of potash.
4. Borax glass and common borax.
5. Flour.
6. Black flux substitute.
7. Argol (or cream of tartar).

8. Common salt.
9. Carbonate of ammonia.
10. Nitre.
11. Wood charcoal.
12. Silica.
13. Lead (sheet and granulated).
14. Litharge.
15. Iron (nails and wire).
16. Silver.

1. *Bi-Carbonate of Soda* (chemical name, hydro-sodic-carbonate).—This is the ordinary commercial bi-carbonate, and needs no preparation, save to be ground free from lumps. It is employed in the crucible assays of gold, silver, copper and lead ores. Its action is desulphurizing (that is, it removes the sulphur from ores fused with it, forming sulphide of soda), and oxidizing (that is, converting certain metals, as iron, tin and zinc, which may have been in the ores treated, from the metallic state to their corresponding oxides), by means of the carbonic acid it contains. Being so readily fusible, it acts as a wash to

rinse down from the sides of the crucible any matters which may be adhering thereto.

Finally, it has a most important bearing as a *flux*, meaning that it forms a fusible compound with certain impurities of the ores, as metallic oxides, etc.

2. *Carbonate of Potash* (potassic carbonate).—Ordinary carbonate (*not* bi-carbonate) of potash. Since a mixture of the alkaline carbonates (*i.e.*, carbonates of potash and soda), is somewhat more fusible than either alone, the use of this carbonate is advisable in crucible assays, particularly of gold and silver ores. It should be ground to a fine powder and kept from the air, as otherwise it would rapidly absorb moisture. Its action is the same as that of the bi-carbonate of soda.

3. *Cyanide of Potash* (potassic cyanide).—The cyanide which is sold in cakes can be used, after being pulverized, or, what is better, the so-called granulated cyanide, which is fine enough for all purposes. In case that in form of cakes is on hand, it must be finely

pulverized, which ought to be done in the open air, using an iron mortar, the top of which is tied over and around with a towel. Also it is well to breathe through a wet cloth wrapped around the head across the nostrils, for the cyanide is so poisonous that inhaling the fine dust even is a dangerous practice. Use the box sieve for sifting. Keep from the air, as this salt absorbs moisture therefrom.

Employed in the lead assay. Action desulphurizing and reducing (that is, taking away the oxygen from metallic oxides and so reducing them to the condition of metals; it is the reverse of oxidizing).

4. *Borax Glass* (sodic bi-borate). — The most valuable flux the assayer possesses. He employs it both for the crucible and scorification processes for gold and silver ores, and the crucible process for copper and lead ores. It has a neutral action. The unfused borax, in powder, is often used in the lead assay.

The ordinary borax of the shops contains from 30 to 47 per cent of water of crystalliza-

tion, which must be gotten rid of before the borax is fit for use. Borax, on being strongly heated, swells very considerably while losing this water, and then gradually sinks down into a clear liquid, which, on cooling, becomes the glass.

Take a large size sand crucible ("S" of Battersea make) and carefully coat its interior with either dry chalk or chalk wash. Place this in a hot fire, and drop in small pieces of borax, letting the swelling subside somewhat after each successive addition. It is well not to allow the crucible to become more than one-third full of the melted borax, as, in spite of the chalk lining, it is liable to attack the crucible and run through.

When thoroughly fused, appearing like water, pour into a frying pan coated with chalk or ruddle, and let cool. Powder in an iron mortar and sift through a 40-mesh sieve. That which goes through had best be reserved for crucible mixtures; the moderately coarse remaining on the sieve will do for scorifications.

A strong iron coffee-mill with teeth or jaws close together, will crush borax glass very finely, and in much less time than it can be done with mortar and pestle.

An iron crucible can be employed in place of the sand one. It will color the borax somewhat, which, however, does no damage.

5. *Flour*.—Wheat flour is serviceable in the lead assay, its action being reducing. But it is more commonly employed together with bi-carbonate of soda, forming what is known as

6. *Black Flux Substitute*.—A mixture of ten parts bi-carbonate of soda and three of flour. It can be used to great advantage in the crucible assays of all of our four metals.

7. *Argol* (crude bi-tartrate of potash; when pure called cream of tartar or hydro-potassic tartrate).—This is a good reducing agent, and is much used in the lead assay, and in crucible charges for gold, silver and copper ores. Whether employed as argol or cream of tartar, its reducing power should be determined. (See page 121).



8. *Common Salt* (sodic chloride).—Ordinary table salt. Very useful in every crucible assay. It serves somewhat as a protecting cover, and as a wash, bringing down from the sides of the crucible adhering metals or fluxes. If moist, place in frying pan and heat till dry, then crush free from lumps.

9. *Carbonate of Ammonia* (ammonic carbonate).—Of very little importance, save to assist in the roasting of certain ores. It exerts a desulphurizing action. To be employed as a fine powder.

10. *Nitre or Saltpetre* (potassic nitrate).—Ordinary saltpetre of commerce. Is a basic flux and oxidizing agent, and is used in the crucible assays of gold, silver and lead ores. Pulverize finely and keep dry. Determine oxidizing power as shown on page 122.

11. *Wood Charcoal* (carbon, more or less impure).—Very valuable on account of its reducing and desulphurizing properties. It exercises the latter action when employed in the roasting of antimonial and arsenical gold

and silver ores. Let it be in a fine condition, keep dry, and determine reducing power in same manner as for argol or cream of tartar. (See page 122.) One gramme of ordinary wood charcoal will reduce from 28 to nearly 32 grammes of metallic lead from litharge, according to the purity of the charcoal. In the scorification assay of certain ores (arsenical, antimonial, etc.), charcoal exerts a beneficial action in breaking up the crust which sometimes forms on the surface of the charge. A few pieces of roughly pulverized charcoal introduced into the matrass in parting gold bullion, excite local action and so prevent the bumping of the nitric acid solution.

There are quite a number of substances containing *carbon* in varying proportions, which, for the sake of their reducing action, might be used as substitutes for cream of tartar and charcoal, but not one of them is so effective as either of the two mentioned, and since the latter are so easily obtained, I refrain from even listing the others.

12. *Silica* (silicic di-oxide).—This is a valuable *acid* flux, that is, it is to be used as a flux for ores which are *basic* in character (as calc spar, dolomite, barytes, fluor spar, etc.), also for ores containing large quantities of iron oxides and carbonates and with little or no silica. It is required for the assays of certain ores of gold and silver in both the crucible and scorification processes, as will be shown. The best form in which to use it is as *precipitated silica* (sold very cheaply), since it is then in a very fine state of division suitable for intimate mixture with ores and fluxes. It should be perfectly dry.

As substitutes, in emergencies, fine, clean, dry sand can be used, and some kinds of glass (which are silicates of soda or potash, with lime, lead, etc.). Lime glass is to be preferred, but on no account is lead glass, or any containing arsenical compounds or easily reducible metallic oxides, to be employed. Common window glass and ordinary bottle glass, broken finely, will serve, and will be

found to be free from objectionable metallic ingredients.

There is no advantage gained in using these substitutes, since the precipitated silica answers admirably, only it is well to know *what* to make use of, in case supplies run out.

13. *Lead*.—In thin sheets, called lead-foil, this metal is occasionally necessary for cupellations, as described under the assaying of gold and silver, and in the gold bullion assay. It should be tested for silver. (See page 120).

In the granulated form (when it is sometimes called test lead) lead is as invaluable as borax glass for the scorification assay. It can be purchased of varying degrees of fineness and purity, or it can be made from bar lead by the assayer himself, as here directed.

Melt pieces of the bar lead in any convenient vessel (odd sizes of sand crucibles, for instance), and when it is of a temperature just hot enough to char a splinter of wood, pour into a compactly-joined cigar box without a cover, or a strong starch box. Imme-

diately give a gentle rotary motion to the contents of the box, till the lead begins to thicken, and emits a slight creaking noise, when the motion is to be increased to a final vigorous shaking from side to side. A minute or two of this latter, and the thing is done. Sift through a 20-mesh or an ordinary flour sieve, and remelt that which remains on the sieve. When the entire batch has been thus granulated, assay for silver, following the directions on page 118.

14. *Litharge* (plumbic mon-oxide, yellow oxide of lead).—Employed mainly for the crucible assays of gold and silver ores. It should be dry, and free from any considerable amount of red oxide of lead, as this causes oxidation of silver, and consequently loss. Mitchell says: "Ordinary litharge can be easily freed from this oxide by fusing it and pouring it into a cold ingot mould, then pulverizing, and carefully keeping it from contact with air, as it readily absorbs oxygen, and if it be allowed to cool in the atmos-

phere, it will nearly all be converted into the red oxide."

Litharge can quite easily be procured free from large quantity of red oxide, and if it is kept in a tightly-stoppered bottle or tin can with closely fitting cover, there is little danger of conversion to this oxide.

It is used to furnish metallic lead that serves as a solvent for the precious metals in the ore. When in the melted state it has the power of giving up its oxygen to almost all the metals (save gold, silver and those of the platinum group), converting them into oxides, and since these are generally extremely fusible, they go into the slag. Thus we are able to separate gold and silver from any baser metals they may be combined or associated with.

Litharge is a very powerful desulphurizing agent (see Mitchell, pp. 181 to 187), and also serves as a metallic flux.

It may safely be stated that *all* litharge contains silver to a greater or less degree.

It may be, and generally is, in small quantity, but it is absolutely necessary to determine the amount, and to allow for it in the calculation of silver in any ore tested.

For the determination of this, see page 116.

White lead (ceruse, plumbic carbonate, or carbonate of lead), and sugar of lead (plumbic acetate), can be made use of as substitutes for litharge, but they do not act quite so well.

15. *Iron*.—A good desulphurizing agent, and as such is much employed in the assay of galena or sulphide of lead. Wire of  $\frac{1}{16}$  inch diameter, and eight-penny nails are the correct sizes. Iron filings can sometimes be used.

16. *Silver*.—Can be bought as very thin foil. It is quite often needed in *inquartation* (which see). It should be tested for gold by dissolving  $\frac{1}{2}$  gramme in pure nitric acid. After the solution is complete, there should be no black specks (gold), no matter how small, in the liquid. There is generally no difficulty in procuring silver perfectly free from gold.

## WET RE-AGENTS FOR ASSAYING.

The *wet* re-agents necessary in the assaying of our chosen four metals, are but two in number ; *distilled water* and *nitric acid*.

1. *Distilled Water*.—It is not worth the while to give directions for the preparation of this liquid ; it is simply to boil water and condense the steam by those means most convenient to the assayer. It can be purchased in the large cities, but is quite expensive. Pure rain water is a very fair substitute. The main point in any case, is to see that it contains no *chlorine* (indicating generally, chloride of sodium or common salt). Test the water for this element, by acidulating a clear sample with *pure* nitric acid, and adding a drop or two of nitrate of silver solution (made by dissolving one part of the dry nitrate of silver in twenty parts of distilled water). The water should remain perfectly clear, that is, there should not be in it the slightest cloudiness or turbidity. If it does show this, reject, and prepare or secure a fresh supply.



2. *Nitric Acid* (hydric nitrate).—Indispensable for *parting*, i.e., the separation of silver and gold by dissolving out the former. It can be procured perfectly pure, but should always be tested for *chlorine*, in same manner as for distilled water. Should it contain this objectionable ingredient, it can be removed by adding *one drop* of nitrate of silver solution and letting the acid stand in the light till the purple-black precipitate of chloride of silver settles to the bottom of the bottle. Then add a second drop, and let remain undisturbed as before. Continue these successive single drop additions until finally the last drop ceases to form any precipitate or milkiness in the acid. Draw off the clear acid and keep tightly stoppered. There are two reasons why chlorine should not be found in the nitric acid. First, it will tend to throw down, as silver chloride, the silver dissolved out of a bead by the nitric acid in the process of parting. Secondly, it indicates the presence of hydrochloric acid, and this acid forms *aqua regia* with the nitric

acid, which could easily dissolve the very small amounts of gold sometimes left after parting.

#### RE-AGENTS FOR ANALYSIS.

The other re-agents, wet and dry, used in the qualitative tests, analyses, and special processes, are the following :

*Alcohol*.—Wanted in the copper analysis and perhaps as fuel for a lamp. Use common alcohol.

*Ammonia Water* (ammonic hydrate, caustic ammonia, aqua ammonia).—If very strong, dilute one part with two parts of distilled water.

*Bi-chromate of Potash* (potassic di-chromate).—Used in the volumetric determination of iron. Should be procured pure.

*Black Oxide of Manganese* (manganese dioxide).—Necessary to aid in the preparation of chlorine gas. Does not need to be perfectly pure.

*Caustic Potash* (potassic hydrate). — One part of common stick potash, dissolved in ten parts of water.

*Chloride of Barium* (baric chloride, muriate of baryta).—One part of the pure salt dissolved in ten parts of distilled water.

*Citrate of Ammonium* (ammonic citrate).—Dissolve one part of the salt in ten parts of distilled water.

*Ferrocyanide of Potassium* (potassic ferrocyanide, yellow prussiate of potash).—One part of the pure salt, dissolved in twelve parts of distilled water.

*Hydrochloric Acid* (muriatic acid).—To be pure. One bottle may be of the concentrated, a second of a mixture of one part acid with four parts of distilled water.

*Hyposulphite of Sodium* (sodic hyposulphite).—Employed in both the volumetric determination of manganese and chlorination test for silver, which see.

*Iodide of Potash* (potassic iodide).—Wanted in the volumetric determination of manganese and as a test re-agent for lead. When used for the latter purpose, it may be either in the solid form, or in solution in water—one part in ten.

*Lime Water* (calcic hydroxide).—Place a very little slaked lime in a bottle; fill with water and shake. Keep tightly corked, and, when wanted, draw off the clear liquid without disturbing the sediment.

*Mercuric Chloride* (corrosive sublimate).—Needed only for the volumetric determination of iron, which see.

*Metallic Copper*.—Wire for battery purposes, and sheet for amalgamation test in panning (which see), will be needed.

*Metallic Mercury*.—Some that is impure can be employed to amalgamate the zinc plates of a battery, and some *free from gold and silver* will be wanted in the various amalgamation tests.

*Metallic Zinc*.—In plates, forming a part of a battery. As a re-agent, zinc in pencils, or granulated, will be needed *pure*.

*Nitrate of Silver* (argentic nitrate, lunar caustic).—See testing of distilled water for chlorine.

*Nitric Acid*.—A bottle of pure and concen-

trated acid, and one of the common commercial (concentrated) for battery, should be on hand.

*Stannous Chloride* (proto-chloride of tin, "tin salts").—For the volumetric determination of iron.

*Sulphate of Iron* (ferrous sulphate, green vitriol, copperas).—In solution in water (of no particular strength) it is used to precipitate gold from its solution as a chloride, after the chlorination assay.

*Sulphide of Iron* (ferrous sulphide, sulphuret of iron).—See next paragraph but one. Can be purchased, or made by holding roll sulphur against a bar of red-hot iron.

*Sulphocyanide of Potassium* (potassic sulphocyanide).—One part of the pure salt dissolved in ten parts of distilled water.

*Sulphuretted Hydrogen Water* (hydrogen sulphide gas dissolved in water).—Very useful in qualitative analysis. To generate it, fit together a simple piece of apparatus similar to fig. 69. The larger bottle, which may be

of any capacity above six ounces, is provided with a doubly-perforated cork, through one hole of which passes a straight glass tube to nearly the bottom of the bottle, and terminating in a funnel. Through the other hole a second tube passes a little way into the larger bottle, and bending twice at right angles, goes through the cork of the smaller bottle to nearly its bottom. A third tube leaves this smaller bottle and connects by a bit of rubber tubing with a fourth tube dipping into the receiving bottle containing distilled water. Place an ounce or two of sulphide of iron broken in small pieces in the bottom of the large bottle and fill half-way up with ordinary water. The small bottle is to be half-filled with distilled water to wash the gas. Pour some common sulphuric acid into the funnel-tube, when the gas will at once be given off. To ascertain when the water in the re-agent bottle is saturated, hold the thumb tightly over its mouth and shake. On releasing the pressure a little the thumb will

be held down if the water is not saturated, but will be forced up, if the contrary is true.

A little glycerine put in the re-agent bottle will help to retain the gas in solution.

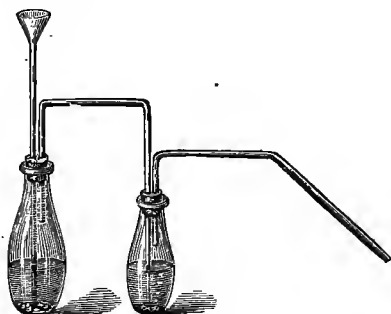


FIG. 69.

*Sulphuric Acid* (oil of vitriol).—A bottle of pure and another of common, both concentrated. If dilute acid is wanted, mix, in a beaker, one part of the acid with five of distilled water.

*Chloride of Calcium* (calcic chloride).—The dry, fused lumps, used to keep moisture away from fine scales. Need not be chemically pure.

*Bone-ash*.—For making cupels, which see. It is best to use a good quality.

*Ruddle* (ferric sesqui-oxide, red oxide of iron, hematite).—A lump for marking cupels and scorifiers, and a paint (prepared by putting an ounce or two of the fine powder with water in a bottle and shaking) for marking crucibles, coating frying-pan, etc., are wanted.

*Chalk and Chalk Wash*.—Ordinary chalk, to be used dry, and the same finely ground and rubbed up with water, for coating crucibles, etc.

*Clay Lute*.—Fire-clay and sand, with solution of common borax in water to bind them together. Horse and cow-hair may also be mixed with them.



## CHAPTER III.

### TESTING OF RE-AGENTS; PRELIMINARY WORK.

BEFORE proceeding to make the regular assays, the student will find it expedient to examine his re-agents, either to ascertain the presence or absence of silver (and in the former case, to determine its quantity), or to learn their various strengths, as shown in their reducing or oxidizing powers.

The following six divisions include all the requisite tests of re-agents, together with one for a special class of ores:

- I. Testing of Litharge for Silver.
- II. Testing of Granulated Lead for Silver.
- III. Testing of Sheet Lead for Silver.
- IV. Determination of the Reducing Powers of Reducing Agents.
- V. Determination of the Oxidizing Power of Nitre (Nitrate of Potash).

## VI. Determination of the Reducing Powers of Certain Ores.

### I. TESTING OF LITHARGE FOR SILVER.

As stated in the chapter on re-agents, almost all litharge contains silver, generally as a small amount. However minute this may be, we must know exactly what it is, and allow for it in calculating the value of an ore.

This we do by the crucible process, in the same manner as we should run an ore. (See Part II, Chapter I.)

Mix *very thoroughly* the particular lot of litharge to be examined, and sample as usual.

Make the charge

Bi-carbonate of soda.....	4 A. T.
Carbonate of potash.....	$\frac{1}{4}$
Litharge.....	4
Charcoal.....	0.7 gramme
Salt cover.	

Mix everthing well, and brush into an "S" Battersea crucible or its equivalent ( $4\frac{3}{4}$  inches by  $4\frac{1}{8}$  wide).

Have the fire quite hot, and heat crucible

till contents are in quiet fusion, which will be in from twenty-five to thirty-five minutes. Take out, let cool, break, and hammer button into shape.

If the button is too large for any cupel reduce by scorifying, then cupel. (See "Scorification and Cupellation," Part II, Chapter I.)

Weigh the resulting silver button, and divide its weight by four; the quotient will be the number of milligrammes (and fractions) of silver per assay ton that the litharge contains.

Several lots of litharge I have tested carried 0.75 ( $\frac{3}{4}$ ) of a milligramme per assay ton, and as the amount of litharge required for an ordinary crucible charge is 2 assay tons, the amount of silver to deduct from a silver bead obtained from an actual assay, would be 1.5 milligrammes.

The above amount, equivalent to  $1\frac{1}{2}$  ounces per ton of 2,000 pounds, is of course very small, and, in the calculation of the value of an ore running say 100 oz. and upward, need

not be deducted from the weight of the silver bead, since the loss of silver by absorption and volatilization from such a bead while cupelling, would more than counterbalance it. But it is very important that it should be deducted in the case of a poor ore, and especially when there is a question as to the presence or absence of silver in any ore.

For the sake of practice, it will be well for the student to perform this crucible assay of litharge three or four times.

## II. TESTING OF GRANULATED LEAD FOR SILVER.

As in the case of litharge, all granulated lead must have its amount of silver determined, which is done by the scorification process.

Mix and sample as usual. Weigh very carefully 2 A. T. of the lead, and pour into a  $2\frac{3}{4}$  inch scorifier, and deposit on the top a piece of borax glass about the size of the head of a pin.

Scorify and cupel as shown in the next

chapter, and weigh resulting bead. The weight of the silver bead, divided by two, will give the number of milligrammes or fractions; that one assay ton of the lead contains, which I have found to vary from  $\frac{3}{10}$  milligramme to 1.2 milligrammes.

Make a table of the amounts of silver contained in fractions and multiples of one assay ton, and post it in some convenient place for reference. I give an example of one particular lot:

0.50	A. T.	contains	0.40	milligramme	silver.
1.00	"	"	0.80	"	"
1.50	"	"	1.20	"	"
2.00	"	"	1.60	"	"

If other weights of lead are used, calculate accordingly.

Deduct silver, in proportion due to the amount of lead used, from beads coming from ores ranging less than 100 ounces; above that disregard it, as with litharge. As with litharge make several runnings of the lot of lead.

## III. TESTING OF SHEET LEAD FOR SILVER.

Sheet lead can generally be purchased remarkably free from silver, and as it is seldom that a piece of more than ten or twelve grammes in weight is required, the quantity of silver such a piece will contain, will be exceedingly small. Moreover, its chief use being to enwrap gold and silver beads for re-cupellation, this amount of added silver is too minute to counterbalance the loss of silver by volatilization and absorption. Sheet lead is sometimes employed to aid in cupelling gold beads that have been inquarted, and here a loss or addition of silver is not important.

But should the lead-foil be suspected of carrying any quantity of silver, its exact amount can be determined by cutting off from various parts of the foil, and in small shreds, two or four assay tons, which are to be scorified and cupelled as usual.

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 IV. DETERMINATION OF THE REDUCING POWERS  
OF REDUCING AGENTS.

1. *Argol* (p. 98).—Weigh out the following charge :

Bi-carbonate of soda.....	1 A. T.
Carbonate of potash.....	$\frac{1}{8}$ “
Litharge .....	1 “
Argol .....	2 grammes
Salt cover.	

Put into a small crucible (size “V” of Battersea), place in a hot fire, cover, remove when thoroughly fused, cool, detach button from slag, weigh, following the directions given for the crucible assays of gold and silver.

The result, divided by two, will give the number of grammes of metallic lead that one gramme of argol is able to reduce from litharge. It ranges around 8.5 grammes.

2. *Cream of Tartar*, or bi-tartrate of potash (p. 98).—Same charge as above, excepting that the two grammes of argol are to be replaced by three grammes of the tartar. One

gramme of pure tartaric acid will reduce 6 grammes of lead, and the same amount of ordinary cream of tartar will reduce 6.4 grammes of lead.

3. *Charcoal* (p. 99).—Make up this charge:

Bi-carbonate of soda.....	2 A. T.
Carbonate of potash.....	$\frac{1}{4}$ “
Litharge.....	2 “
Charcoal.....	1 gramme
Salt cover.	

Use an “S” crucible, and treat as before. As previously stated, the reducing power of one gramme of charcoal varies between 28 and 32 grammes of lead.

#### V. DETERMINATION OF THE OXIDIZING POWER OF NITRE (NITRATE OF POTASH).

Determine the oxidizing power of the fine, dry salt (p. 99), by the following charge (Ricketts' modified):

Bi-carbonate of soda.....	2 A. T.
Carbonate of potash.....	$\frac{1}{4}$ “
Litharge.....	2 “
Charcoal.....	1 gramme
Nitre.....	3 grammes
Salt cover.	



Use an "S" crucible and treat as in the previous crucible operations. The difference between the weight of the lead button obtained and that found in the assay of the charcoal, divided by three, will give the oxidizing power of the nitre, per gramme. It is about 1 gramme.

#### VI. DETERMINATION OF THE REDUCING POWERS OF CERTAIN ORES.

Certain ores exert a reducing action upon litharge, which action is injurious only in that it increases the weights of the lead buttons obtained by crucible assays, thus necessitating their being scorified down to a size suitable for cupellation.

Antimony, arsenic, sulphur and zinc are the elements which effect the reduction, and in case they are present in large quantities, they can be removed in the manner indicated under "Roasting" in Part II, Chapter I.

It is not often necessary to determine the reducing powers of such ores, especially with

the advanced assayer, for he learns by experience, by a single glance at a specimen, how to allow for them in his assay, by noting the comparative amounts of the four undesirable constituents.

When, however, such information is wanted, prepare the following charge :

Bi-carbonate of soda.....	1	A. T.
Carbonate of potash.....	$\frac{1}{8}$	“
Litharge.....	1	“
Ore .....	$\frac{1}{10}$	“
Salt cover.		

(See Ricketts, pp. 66–67.) Fuse in as short a time as possible, cool, break crucible, etc., etc. One of three results will happen. The  $\frac{1}{10}$  A. T. ore employed will produce :

1. No lead, or less than three grammes.
2. Three grammes.
3. More than three grammes.

To illustrate by an example : Imagine that for the actual assay 1 assay ton of the ore is to be used, this quantity being the usual charge for a crucible running. Should the  $\frac{1}{10}$  A. T. ore reduce 1.2 grammes of lead, then 1

A. T. would, of course, reduce 12 grammes. This is indeed a very good weight to cupel, but if we wanted the button a little heavier, say 16 grammes, we should be obliged to add argol, cream of tartar, charcoal or other reducing agent to make up the balance of 4 grammes. Assuming 1 gramme of charcoal to reduce 28 grammes of lead, then  $\frac{1}{7}$  of a gramme or about 150 milligrammes would be an amount that would produce the 4 grammes very nearly.

In the second case, if  $\frac{1}{10}$  A. T. ore reduced 3 grammes, 1 A. T. would reduce 30 grammes, a little too heavy a weight, which could be obviated by using only  $\frac{1}{2}$  A. T. of the ore for assay, producing a button of 15 grammes, or oxidizing as in the third supposition.

“If the reducing power corresponds to the third case, divide the excess of lead by the oxidizing power of nitre; the quotient will show how much nitre is needed.”

Examine the slag, to correct or to duplicate it in the actual running of the ore.



PART II.  
ASSAYING.



## PART II.

### ASSAYING.

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#### CHAPTER I.

##### GOLD AND SILVER ORES.

OCCURRENCE.—Gold is found in large quantities in the native state, designated by the various names of free gold, flour, leaf, wire and nugget gold. The minerals which most frequently carry gold are oxide of iron, pyrites of iron and copper (known as auriferous sulphurets), arsenopyrite, and tellurium ores; of these, the most abundant are the first two.

Minerals which less frequently are gold-bearing, are galena, blende, gray copper and “carbonate ores.”

For a classification of silver ores I quote from Kustel's "Roasting of Gold and Silver Ores":

"IMPORTANT SILVER ORES.

The most important silver ores are those found in such quantities as to be an object of metallurgical operations. The principal minerals of this kind are the following:

*A. Silver ores with unvariable amount of silver.*—*a. Sulphuret of silver*, or silver glance, with 87 per cent of silver. It is of common occurrence. *b. Brittle silver ore (stephanite)*, or sulphuret of silver and antimony. This mineral contains 68 per cent of silver, and is quite common. *c. Polybasite*, sulphuret of silver, antimony and some arsenic, with 75 per cent of silver. *d. Ruby silver*. The dark red silver ore, or antimonial variety, with 59 per cent, and the light red silver ore, or arsenical variety, with 65 per cent of silver, are valuable minerals. *e. Miargyrite*, sulphuret of silver and antimony; 36.5 per cent of silver. *f. Horn silver*, or



chloride of silver, with 75 per cent of silver.  
*g. Iodic and bromic silver* of yellow and green colors.

*B. Argentiferous ores with variable amount of silver.*—*a. Stromeyerite*, or silver copper glance, a sulphuret of silver and copper containing up to 53 per cent of silver. *b. Stetefeldite*, with 25 per cent of silver, is an oxide ore. *c. Silverfahlore*, argentiferous gray copper ore. It contains silver in very variable proportions up to 31 per cent. This ore is quite common, and for this reason is important. It is also one of the most rebellious ores, containing copper, antimony, arsenic, sulphur, lead, iron, zinc, and sometimes gold and quicksilver. *d. Chloride ores* (so-called), mostly decomposed ores, generally of an earthy appearance and different colors. They contain more or less finely divided chloride of silver.

*C.*—*a. Argentiferous lead ores*, galena, or sulphuret of lead, lead glance. Generally, this is not rich in silver, containing from \$20 to

\$60 per ton. Specimens assay sometimes as high as \$300.\* *b. Cerussite*, carbonate of lead. If pure, without admixture of copper and other carbonates, it is poor in silver in most cases. *c. Argentiferous zinc blende*, sulphuret of zinc. Pure zinc blende contains usually only traces of silver; often, however, it assays well, even up to \$400 per ton. *d. Argentiferous pyrites*. Copper and iron pyrites are poor in silver, but often auriferous.

There are, besides, numerous classes of decomposed silver ores, generally of earthy nature; also, half decomposed ores which have lost their metallic glance, having a black or bluish-black color, and being generally cupriferous." †

•  
ASSAY.—We can best consider the systematic fire treatment of gold and silver ores, by dividing it into a series of operations, and taking each in turn and in detail.

\* I have found them as high as \$1,500 per ton. (W. L. B.)

† See appendix for extended lists of the minerals of or containing gold and silver.

The three main divisions are :

- I. Preparation of the sample.
- II. Scorification process.
- III. Crucible process.

#### I. PREPARATION OF THE SAMPLE.

The first thing to be done in the treatment of an ore, whether it is to be assayed for gold, silver, copper, lead, or any other metal, is to *place* it, that is, to label it. This is best accomplished by giving to it a running number, never to be repeated. By adopting this system of numbering all samples, any danger of confusing specimens from various mines or parts of the same mine or vein, is entirely gotten rid of. Have a notebook at hand, and, in it, under the number, write such items as may be necessary or useful, as the date when sample was received, name of person sending it, character of the ore, nature of the charge, weights employed, calculations, etc. To pieces of the ore which are to remain whole, affix gummed labels, bearing the same

number. To preserve the final pulverized samples, bottles of about four ounces capacity, cork-stoppered, and similarly labelled, can be employed, or what is even better, pasteboard boxes in size about  $5\frac{1}{2}$  inches long by  $3\frac{1}{2}$  inches wide and 2 inches high, will be found to be very serviceable. They can be written on, thus requiring no labels.

The next step is to secure an *average sample* for assay, and its importance cannot be over-rated. An ore is by no means of uniform character, being, in general, made up of the gangue or valueless portion of the ore, through which are scattered the valuable minerals. Therefore, unless the sample finally chosen for assay represents an average of the entire lot, being a mixture in the same proportions, of the richest, the medium and the poorest portions, as in the original ore, the assay itself is worthless, no matter how carefully it may have been performed.\*

\* In this connection, I would refer the student to an article "On the Commercial Sampling of Minerals," by Mr. L. S. Austin, of Salt Lake City, Utah, which appeared in the "Engineering and Mining Journal" (July 22, Aug. 5, Aug. 26, and Sept. 16, 1882).

To illustrate the averaging, take a quantity of ore weighing fifty pounds, which may be as a single lump, or, better, the result of the selection of samples across a section of the vein. In order to get a fair average, it is not necessary to operate on a larger quantity than this amount, for above it, should come in, as a more practical test, the mill-run.

With a heavy sledge-hammer, break up the entire mass into pieces of about the size of a hickory-nut, transfer to a large sheet of heavy brown or manilla paper, then, with a large iron or steel spatula, thoroughly mix, by turning over and over and by stirring in together with the dust, the finer and coarser particles, till satisfied that the whole is a homogeneous mixture.

(At this stage of the operation, it is a good plan to reserve a characteristic lump or a few pieces, from an examination of which the nature of the ore may be determined, and process of treatment decided upon.)

Now divide in halves, and break up still

finer (to the size of a hazel-nut or less) the half selected. Mix again and halve as before. Continue the crushing, mixing and halving until about one pound has finally been sampled down.

When the ore to be assayed is less than fifty pounds, ranging down to a pound or two, it can be broken still smaller in the successive steps, and when it is but a few ounces in weight, the whole of it should be crushed and pulverized, as directed. Wet or damp ores and pulps should be dried before pulverizing.

The student must exercise his judgment in a measure, with regard to the sampling of an ore, simply remembering that the object, as before stated, is to obtain a final product which shall be an exact counterpart, in relative proportions, of the metals and gangue of the original ore.

Instead of halving, the broken ore may be taken up on a sampling shovel, and thrown on a tin or copper sampler, making it a rule to reject either all that which goes between

the prongs or ribs, or that which remains upon them. These two articles are convenient, but not necessary.

The third step is to pulverize the sample finally obtained, which may be done very simply though somewhat laboriously (depending considerably upon the nature of the ore), by means of an iron mortar and pestle. A towel wrapped loosely around the pestle and across the top of the mortar will prevent loss due to flying particles.

Sift through a sieve of eighty or ninety or even of one hundred meshes, since the finer the powder, the more quickly will it be acted upon in the furnace. Do the sifting over a piece of brown paper, and be sure that *all* the sample passes through the sieve, for the few minute particles or scales, that might remain on the sieve and be hastily thrown away, could be of sufficient value to vitiate the assay. (See in appendix, "Assaying of Ores Containing Free Gold or Free Silver".)

Mix again the fine powder, and with a large

brush transfer to the properly marked box or bottle, when the sample is ready for assay.

When very many assays have to be performed daily, the rubbing-plate and rubbers will be found so very convenient and so time-and-labor-saving, that they will become almost necessities. (See pp. 21-24 for description and method of using.)

In place of the sheets of brown paper already mentioned, and which quickly become soiled and full of holes, the zinc sifting-pans (p. 26, fig. 7) can be used to advantage.

To guard against loss of dust, the tin box-sieve (p. 26) is recommended.

Having brought to the requisite degree of fineness the sample of ore to be assayed, the next thing to be done is to select its method of treatment.

There are two methods of assaying gold and silver ores, the scorification and the crucible.

The process to be chosen depends chiefly



on the nature of the ore. In general, we may say the scorification process is better adapted for *all* silver ores, and for *rich* gold ores (including telluride ores of any degree of richness).

The crucible process serves better for *low grade gold ores*. The advantage of this process lies mainly in the fact that it enables us to operate upon a larger quantity of ore; otherwise it is no better than the scorification method and indeed in many respects the latter is to be preferred.

The scorification process is so much simpler to use, easier to comprehend, and so satisfactory in its working, that I shall give it the greater prominence in this manual.

## II. SCORIFICATION PROCESS.

The object of this process is to so act upon an ore with heat, access of air, and certain re-agents, that the precious metals shall be driven out of their combinations with the impurities of the ore (or if free, separated

from them), and be retained alloyed with another metal, lead, and from which they can afterwards be separated.

The chief re-agents are lead, in a granulated condition, and borax glass.

Besides these, silica, iron, and bi-carbonate of soda are occasionally employed.

The ore, mixed with the lead, and covered with the borax glass or other flux, is put into a scorifier and subjected to heat in a muffle.

Under the action of the heat, the lead melts, and being scattered throughout the ore, seizes upon the gold and silver and settles with them to the bottom of the scorifier. The borax glass or other flux attacks the gangue and impurities present, and uniting with them and with litharge resulting from oxidation of some of the lead, forms a slag or glass, which floats upon the surface of the molten lead.

So much for the theory of scorification; in practice we follow in regular rotation the steps here given:

- 
- a.* Preparation of Charge (including weighing of ore, roasting, weighing of re-agents, mixing, etc).
  - b.* Scorification.
  - c.* Cupellation.
  - d.* Weighing the Gold and Silver Bead.
  - e.* Parting.
  - f.* Inquartation.
  - g.* Weighing the Gold Residue.
  - h.* Calculations.

*a. Preparation of Charge.*

Whatever subsequent treatment an ore is to undergo, the quantity required for assay must be weighed first. Certain ores may possibly be subjected to a preliminary operation known as roasting, but the ore must be weighed out before this, not after.

If the ore in question is in a bottle, pour all out upon a clean piece of black glazed paper or piece of sheet rubber, or if it is in a box, it can be sampled therein. Weigh the amount desired, sampling from various parts of the ore.

*Roasting.*—Whenever an ore contains a large amount of antimony, arsenic, sulphur or zinc, it can be first roasted, that is, heated till the above mentioned substances are driven off. This roasting is not often done, but when it is advisable to do it, follow the directions herewith given.

The roasting of ores for the scorification process is performed as follows:

The carefully weighed ore is transferred to a roasting-dish, and placed in the forward part of the muffle before the latter has reached a dull red heat. The ore is to be continually stirred with a stout wire having a loop at the end at right angles to the wire. Shortly, minute sparks will be thrown off, and the ore will begin to glow in places like burning charcoal. Stirring must be kept up till the glowing ceases, and the whole seems of one color. It should yield to the stirrer like dry sand, have no metallic lustre, and contain no hard lumps or pieces adhering to the roasting-dish. The dish and contents can now be moved to

the hottest part of the muffle and left unstirred till fumes have ceased coming off, when the ore is said to be "sweet." When finished, take out, cool, and brush ore from dish.

If the ore is almost entirely pyrites of iron, it needs no additional treatment during or after the roasting. If it be a mixture of iron pyrites and copper pyrites, with the latter predominating, or copper pyrites alone, after taking out of the muffle and allowing to cool, mix with a little carbonate of ammonia, cover with another roasting-dish, and return to a moderately warm part of the muffle till the fumes have again ceased. Such sulphates as have been formed by the oxidation of sulphur in the ore are now converted into sulphate of ammonia, which being very volatile is quickly driven off.

If the ore should contain much sulphide of lead (galena), or sulphide of antimony, mix some fine sand (or precipitated silica) with it while roasting, as without it the minerals mentioned would soon fuse, cake together and

adhere to the dish, thus spoiling the assay. One fifth of an assay ton of ore will require one gramme of silica, and so on.

If much antimonial and arsenical compounds is present in the ore, it is advisable to mix some charcoal, finely ground, with the ore, in order to decompose the antimoniates and arseniates formed. Let all the charcoal be burned out before removing from the furnace.

I may add that in case the ore is a sulphide (of whatever metal), with very little gangue, it is best to add silica in roasting, in the proportion given above.

If the laboratory is provided with gas, the ore can be roasted in the usual roasting-dish over the flame of a Bunsen burner, which will work very nicely, as the temperature can be regulated to any degree.

To continue with the preparation of the charge: Number or letter the scorifier with ruddle (liquid or lump), weigh the requisite amount of granulated lead, divide approxi-

mately in halves, and transfer one half to the scorifier. Upon it brush the ore (roasted or not) and mix by means of a small steel spatula. Pour the remaining half of the lead evenly over the surface of the mixed ore and lead, and over all sprinkle the borax glass. In similar manner prepare all the other charges.

A deviation from this method has been followed by some assayers. Their procedure is to put, say  $\frac{1}{4}$  of the lead at the bottom of the scorifier, then the ore and  $\frac{1}{2}$  of the lead mixed previously, topping all with the remaining  $\frac{1}{4}$  of the lead. This change is due to the fear of unacted-upon ore remaining at the bottom of the scorifier. I am inclined to consider it an almost unnecessary refinement.

In many assaying establishments, notably the larger ones, the practice of marking scorifiers, cupels and crucibles does not obtain. Instead of this, a systematic order of arranging these articles is kept up, either in or out of the furnace, and this routine of position and order of working is never varied, so that by

relative place a sample can always be identified. This plan is indeed a good one, and perhaps imperative where very much work is done, but for the beginner, for a time at least, the custom of marking everything had better be adopted.

*b. Scorification.*

Place the scorifiers, by means of the scorifier tongs (page 61, fig. 29) in the middle and back of the muffle, which should be *decidedly hot*, close the door and augment the draft.

Then begins the first operation, the melting or fusion of the lead, due to intense heat and absence of oxygen, which takes from three to four minutes.

When the lead is liquid, open the door, thus admitting a current of air to supply oxygen, and which will also tend to diminish the heat somewhat.

Now, in the case of ores containing or retaining antimony, arsenic, sulphur or zinc, a second operation, roasting, begins and con-



tinues till the greater proportion of the substances named have volatilized, the remainder of them going into the slag.

During this time, the borax glass has melted and begun uniting with the gangue of the ore and with oxide of lead to form a slag which surrounds as a ring the molten lead.

As the scorification goes on, the melted lead grows smaller and smaller by oxidation and the volatilization of the greater part of the oxide formed, while the ring of slag gradually closes in and finally covers the lead, which is seen no more.

Finally increase the heat for a minute or two to fully liquefy the slag, which will finish the process of scorification.

Remove the scorifiers, and pour their contents into the cups of the scorification moulds (page 65, figs. 37 and 38), which should not be cold, covering each receptacle with its proper scorifier to retain its identification. (If *necessary* these scorifiers can be again employed for ores, etc.)

Instead of pouring, the leads can be allowed to cool in their scorifiers, but no advantage is gained by this, and they take a longer time to cool.

In either case, however, when cold, detach the lead buttons from their slags, and hammer each button into a clean cube with flattened corners (fig. 70). Were the corners to be left sharp, they would injure the cupel when the button came to be dropped into it.



FIG. 70.

The weight of the button will vary according to the conditions ; the nature of the ore, the size of the charge, the heat of the furnace and the length of time the charge was allowed to remain in it, all exert an influence. A good weight is from twelve to sixteen grammes, which will make a cube of about one-half inch.

The button of lead is to be marked with some identifying number or letter with the point of a file or knife-blade.

The button should be perfectly malleable ; if brittle it has retained antimony, arsenic,

zinc or litharge, which can be gotten rid of by re-scorification. If the button is large no extra lead need be added, if small an assay ton or two may be melted with it.

Again, the button may be very hard on hammering or show red in places, and perhaps on taking out of the scorification mould may have mossy copper on the bottom. In such cases the button must be re-scorified until no more copper is seen, or until it is very malleable. Plenty of lead must be used to alloy with the copper.

Since there is a greater loss of silver by cupellation than in scorification, very large buttons should be scorified down to a size suited to the cupels.

Examine the slag, and if it contains any globules of lead, hammer them flat, then place them on top of the main button and cupel all together.

The slag should be vitreous or glassy, and of uniform character, its color depending upon the nature of the ore.

The scorifier should be perfectly smooth in its interior, that is, it should have no semi-fused lumps adhering thereto. Occasionally it may be corroded or eaten away, which does not necessarily injure the assay, unless the corrosion extends through the dish and allows its contents to flow out upon the floor of the muffle. In such a case (when of course the assay must be repeated) at once cover the floor of the muffle with dry sand or bone-ash, using the muffle shovel (fig. 35), and scrape out the mass adhering to it by means of the hoe or scraper (fig. 39). If this cleaning out of the muffle after an accident by spilling or leakage is not attended to, it leads to either one or both of two evils: first, the melted lead and borax attack the muffle and rapidly eat a hole through it; secondly, they stick to any scorifier or cupel placed in the muffle, making it almost impossible to move or remove either without breakage or loss of contents.

The corrosion of the scorifier is a good hint

to add silica to similar ores, for usually it is the lack of this in the ore that causes the abstraction of silica from the scorifier, though there are times when a mixture of much lead and little ore is being scorified, that the litharge formed by the oxidation of the lead itself attacks the scorifier, and again, as in case of compounds rich in copper (a copper matte for instance), the oxide of copper attacks the scorifier.

Sometimes in the process of scorification a crust forms over the surface of the charge and refuses to break. Such a crust is generally due to arsenical and antimonial ores present, and may often be destroyed by dropping in the scorifier some powdered charcoal wrapped in a wad of thin paper.

The oxidation can also be commenced by stirring the charge with a bent wire, until the lead is uncovered and begins to act. Withdraw the wire, break off the mixture adhering to the end and return it (the slag, etc.) to the scorifier, as it will probably carry some of the ore.

*c. Cupellation.*

This operation consists in oxidizing the lead of the lead buttons, the litharge formed by the heat being partly absorbed by the cupel and partly driven up the chimney, leaving the gold and silver together as a bead upon the surface of the cupel. Other metals that may have remained in small quantity from the previous operations, are also oxidized and so gotten rid of.

Take a good cupel (pages 73-76, fig. 49), in weight about one-third greater than that of the button that is to go in it, blow out any dust or impurities from the interior, mark on its sides in three or four places with ruddle or the point of a file, its appropriate number or letter, and with the aid of the cupel tongs or cupel shovel and hoe, place it in the muffle and there let it remain some four or five minutes that it may acquire the temperature of the furnace.

As can be inferred from the preceding paragraph, the size of the cupel depends

upon the size of the lead button. And as mentioned under cupel-making, it is a good plan to have on hand cupels of various weights. It is stated that a good cupel will absorb its own weight of litharge, and furthermore, it is able to take a button heavier than its own weight, for a large amount of litharge (or oxide of lead) is driven off in fumes and consequently does not enter into the body of the cupel. But it is better to employ a cupel the weight of which is from one-fourth to one-third more than that of the button, for when a cupel becomes nearly saturated with litharge, the cupellation proceeds too slowly, when, on the contrary, it ought to be somewhat hastened, and cases occur that the cupellation ceases, though there may be at the bottom of the cupel enough unattacked bone-ash to absorb the remaining lead.

When the cupel or cupels have been in the muffle a few minutes, and consequently have become of the same temperature as the interior of the muffle, the lead button or buttons

are to be placed in them, each one in its proper cupel, by means of the smaller curved tongs (page 61, fig. 27), and the muffle-door of the furnace closed, having previously, if necessary, placed a couple of pieces of coke or charcoal in the mouth of the muffle.

If the muffle has been of the proper temperature, in a minute's time or less, all the lead buttons will have quietly fused, and, on opening the muffle door, each will be seen as a little lake of molten metal, from which arise fumes of oxide of lead.

The closing of the door at first is simply in order to melt the lead buttons, by the increased heat and absence of air.

It is very difficult to give in words, directions for the proper conducting of this important step of cupellation. Experience is the best instructor.

In general, *do not have the furnace too hot.* This is not a matter of so much importance in the cupellation of the lead buttons from gold ores, but in those from rich silver ores it is such.



“ The heat is too great when the cupels are whitish, when the fused metal is seen with difficulty, and the scarcely visible fumes rise rapidly ” (Ricketts), and *particularly* when the melted lead *bubbles*.

“ The heat is too low when the fumes are thick and fall, and when the unabsorbed litharge forms lumps and scales ” (Ricketts), in short, to speak seemingly paradoxically, when the muffle and contents *look* cold.

An extremely high heat is bad, but a low heat is worse. “ The following are indices of favorable working: The muffle is reddish-white, the cupel red, the fused metal luminous and clear, the lead fumes rise slowly, and the litharge is completely absorbed by the cupel.” So says Ricketts; but concerning the last count, opinions seem to differ. While some assayers think all the lead should be *in* the cupel, others declare the test of good working to be in the presence of scales of litharge around the inner circumference of the cupel. In other words, the “ feathering ” shows that

the fire has not been too hot. Who shall decide when doctors disagree?

All this time, however, the buttons have been growing smaller and smaller, by oxidation and by volatilization and absorption of the oxide, changing from flat liquids to convex ones, and this reduction continues until we reach the point when the last of the lead leaves the bead. This is known as the "brightening," "flashing," or "blicking." As the button of gold, silver and lead arrives near this stage it appears to revolve with great velocity, and rainbow colors succeed each other all over its surface. Finally a film passes over the bead, and then no more action is visible.

(With poor silver ores and ordinary gold ores the final bead is so small that it is difficult, if not impossible, to see the "blicking," but on beads from silver ores of any richness the brightening shows well that the operation of cupellation is concluded.)

Now move the cupel to the hottest place in

the muffle, or increase the heat by closing the muffle door, that the last traces of lead may be driven off. One source of error in silver assays is due to the assayer not getting rid of all his lead from the beads, but instead he weighs and reports it as silver. Better err by under-reporting rather than over, so take the chances of volatilizing a little silver from the bead than to allow lead to remain with the silver. A minute is generally sufficient to drive off the last lead, but with ores containing more gold than silver, let the cupel remain in the hot part three or four minutes, for there is no danger of losing any gold in that time.

Silver beads, on being suddenly brought from the hot interior of the muffle to the front where it is cooler, or out into the open air, sometimes "spit," or "blossom;" that is, the bead sprouts or vegetates, forming foliated protuberances all over its surface. This may occasion loss, as the spitting throws off particles of the silver; hence guard against this as

much as possible by moving the cupel by degrees to the front, and when at the mouth of the muffle cover with an inverted hot cupel. With beads weighing less than 30 milligrammes or thereabouts this need not be done, but above that weight proceed carefully.

If the assayer is running a number of assays, let him so arrange the cupels that those intended for buttons from poor silver ores or gold ores shall be in the centre or hottest part of the muffle, while those for rich silver ores shall be in the fore part or cooler section. The reason for so doing is this: silver is sensibly volatile at a high heat, and the higher the temperature the greater the loss. On the other hand the smaller the percentage of silver in a silver-lead, the less loss of this metal. By therefore placing the rich silver-lead in the cooler portions, the tendency is to decrease the loss by volatilization. With any furnace, the heat of which can not be instantly controlled, the muffle often becomes a little too hot for perfect cupellation. When

but few cupels are therein this does not matter much, since they can be slid to the front ; but it is of importance when the muffle is so well filled that it becomes difficult or impossible to move any particular cupel or group of cupels to a cooler spot. By now putting in the muffle a small *cold* scorifier or cupel, letting it rest on the edges of four of the cupels, the interior can be cooled down considerably. Several scorifiers or cupels thus arranged have quite a lowering effect on the temperature, at least for a time.

When many cupels are being managed at once make a chart of their relative positions in the muffle, that there may be no "cases of mistaken identity" afterwards, for with large buttons in small cupels the litharge often obliterates the ruddle marks.

If the furnace is too cold, cupellation ceases, and the lead button is said to "freeze," forming a buncy mass which undergoes no further action. A piece of charcoal laid upon the cupel, and additional heat applied, will

sometimes finish the cupellation, or the button may be dug out of the old cupel, wrapped in a piece of lead-foil, and be re-cupelled in a new cupel. The result either way is none too accurate.

The final silver and gold bead from any cupellation should adhere with some tenacity to the cupel, have a bright rounded surface, and appear frosted below.

*d. Weighing the Gold and Silver Bead.*

When cold detach the bead from its cupel, using the point of a knife-blade and keeping a finger on the bead while so doing if the bead be small, for otherwise the exertion put forth to loosen the bead might easily snap it out of the cupel and past finding.

Lift the bead from the cupel by means of delicate pincers (p. 84), and cleanse from any adhering cupel dirt, by rolling in the palm, by using a small stiff brush, or, if necessary, by flattening a little by means of a small steel hammer and anvil. If the bead be very small fold it in three or four thicknesses of

tissue paper to prevent its flying away under the strokes of the hammer.

Weigh on the bullion scales in milligrammes and fractions.

*e. Parting.*

The separation of gold and silver by dissolving out the latter is designated by the term "parting."

The bead after weighing is flattened a little if it has not been so treated before. Now place in a little clean porcelain capsule or crucible (fig. 53), and fill about a quarter full with water (free from chlorine, see p. 106), and add four to six drops of concentrated nitric acid. No exact rule as to the amount of acid to add can be given, nor indeed is it necessary. But in general add drop by drop till it begins to "bite" the bead, that is, when the latter seems in violent motion and bubbles are thrown rapidly off. Instead of adding concentrated acid to water containing the bead, until it takes hold of the latter, the assayer may use a diluted acid of known

strength. 16 parts of nitric acid of 41° Beaumé (specific gravity 1.41) with 30 parts of distilled water will make an acid of 21° Beaumé (specific gravity 1.16). This will do for ordinary small beads; for large ones, after having treated them with the above 1.16 acid, add some of 32° Beaumé (specific gravity 1.26), made by mixing 16 parts of the strong 41° acid with 10 parts of distilled water. Make these up in quantity and preserve in well stoppered bottles.

Now place the capsule on a sand-bath or wire triangle, and heat gently, not enough to cause the acid solution to boil. After a time no more action goes on. If there is no gold in the bead, nothing will remain undissolved in the capsule; it will contain only the clear solution of nitrate of silver, formed by the silver dissolving in the acid.

In this case nothing further need be done than to wash out the contents of the capsule into a bottle containing silver residues.

But should one or more black specks be



seen at the bottom of the capsule or floating about in the liquid, gold may or may not be present; at all events, these specks, *however small*, must be treated as though they were gold. Pour off the liquid above the black particles, first lightly tapping the capsule in order to cause the floating gold to settle to the bottom. It is best to pour into another clean porcelain dish, so that should the gold, by some mischance, go over with the outpouring solution, it may be recovered. Fill up the capsule with water, agitate a little and warm gently. This is to wash out the nitrate of silver from the gold. Tap the gold to the bottom, pour off the washings, and repeat the washing. If there is much gold a third washing may be necessary. All this to insure complete removal of the silver nitrate. Finally drain off, wipe the capsule dry, remove, by means of filter paper (or clean blotting paper), any drops of water adhering to the interior of the capsule (being careful not to take away any of the gold), and heat

*very gently* at first till all moisture has been driven off, then intensely for a minute or two. The gold has now changed in color from black to its normal yellow, and is very nearly pure, enough so for all practical purposes. Let the capsule and contents cool.

*f. Inquartation.*

When a bead of gold and silver contains the gold in a greater proportion than about one-third of the silver, it possesses the power of resisting the solvent action of nitric acid. A certain amount of the silver may dissolve, according to the relative proportions of the two metals, but the larger part of it will remain so enveloped by the gold, that the strongest acid will not attack it.

Hence we resort to inquartation or the operation of producing an alloy of gold and silver in such proportion that the latter metal may be extracted by nitric acid.

By the color of the bead the assayer can judge whether it needs to undergo this operation. If it be of a moderately yellow color or

a brighter yellow, it will probably need it. But there can be no doubt of it, if it refuses to be acted upon by the acid.

Remove it from the capsule and dry. Weigh some thin and pure silver foil in quantity about twice the weight of the bead. Wrap the latter in the foil and place both in a cupel (or in a small hole bored in the back of the cupel) and fuse them well together in the flame of a blow-pipe. When cool, remove the now largely-increased bead from the cupel, flatten and part as directed.

Instead of employing the blow-pipe, the bead and silver can be enfolded in some sheet-lead and be re-cupelled in the usual manner. Indeed, if the original bead weighs more than ten milligrammes, it will be easier to alloy it by cupellation than by blow-piping, and a much better fusion be obtained.

*g. Weighing the Gold Residue.* •

By means of a pointed slip of wood or sharp knife-blade, transfer the gold (which should be one scale or film) to the scale-pan

of the bullion balance, and weigh with *exceeding care*, as usual in milligrammes and fractions. It often happens that the minute black pin-point of gold becomes too small to be weighed after the heating. It can then be reported only as a "trace" or "color."

*h. Calculations.*

By the use of the system of assay ton weights, the calculation of the gold and silver value of an ore becomes very simple. Two examples will show this very clearly :

EXAMPLE NO. I.

Amount of ore taken.....  $\frac{1}{6}$  A. T.

Amount of test-lead used.....  $1\frac{1}{2}$  "

	MILLIGRAMMES.
Weight of gold and silver bead.....	8.50
" silver in $1\frac{1}{2}$ A. T. lead .....	.25
	—
True weight of gold and silver bead.....	8.25
Weight of gold in the bead.....	1.10
	—
Weight of silver in the bead.....	7.15

$7.15 \times 5 = 35.75 = 35\frac{3}{4}$  milligrammes =  $35\frac{3}{4}$  ounces per ton of silver in the ore.

$1.10 \times 5 = 5.5 = 5\frac{1}{2}$  milligrammes =  $5\frac{1}{2}$  ounces per ton of gold in the ore.

## VALUE OF THE ORE:

Gold— $5\frac{1}{2}$ ounces @ \$20.67 per oz.....	\$113.68
Silver— $35\frac{3}{4}$ “ “ 1.29 “ .....	46.11
Total value per ton.....	\$159.79

## EXAMPLE NO. 2.

Amount of ore taken.....	$\frac{1}{2}$ A. T.
Amount of test-lead used .....	1 “
	MGRMS.
Weight of gold and silver bead .....	231.90
Weight of silver in test-lead *.....	0.00
True weight of gold and silver bead.....	231.90
Weight of gold, “faint trace”.....	0.00
Weight of silver in the bead .....	231.90

$231.9 \times 2 = 463.8 = 463\frac{8}{10}$  milligrammes =  $463\frac{8}{10}$  ounces per ton of silver in the ore.

Value ;  $463.8 \times \$1.29 = \$597.30$  per ton.

*Charges.*—A charge which serves well for the common run of ores, in which the metals

\* Not deducted. Read remarks on testing of granulated lead for silver, p. 119.

are not in excess of the gangue is the following :

Ore.....	$\frac{1}{5}$ A. T.
Granulated lead.....	$1\frac{1}{2}$ . “
Borax glass.....	200 mgrms.

Use this for ores that do not contain much copper or lead. The weight of the borax glass is put down more to serve as a guide than for any other purpose. It need not be weighed accurately or even weighed at all; after a time the assayer will learn to use it in *pinches*.

For ores with considerable copper, prepare this charge :

Ore.....	$\frac{1}{10}$ A. T.
Granulated lead.....	$2\frac{1}{2}$ “
Borax glass... ..	a trifle.

If arsenic, antimony, sulphur and zinc, either one or all are present, the ore may or may not be roasted.

In the latter case, and when not much of any one of the four elements named is present,

heat gently for a time, till the roasting in the scorifier is done.

If rich in the said elements, a strong heat can be applied at once, melting everything down into a sort of matte, then proceeding as usual.

In compounds *very rich* in copper, as copper mattes, use no borax glass.

With sulphurets not roasted, litharge may be sprinkled over the surface of the charge, and works nicely. Weigh the litharge.

For tellurides, plenty of lead must be used, either in the form of granulated lead or litharge. The buttons may need repeated scorifications (20 parts of lead to 1 of ore).

With chlorides, use as low a heat as possible, all the way through until the charge has covered over, then heat to complete fusion.

With antimonial and arsenical ores, charcoal added during scorification often has a good effect.

Ores having a great quantity of lime or baryta will require more borax glass during

scorification (perhaps as much in weight as the ore taken), and need a good heat.

Oxide of iron ores without silica should have it added : 1 grm. per each  $\frac{1}{5}$  A. T. ore.

For galena,  $\frac{1}{2}$  A. T. with 1 A. T. lead works well. A nail should be placed in the scorifier to aid in desulphurizing.

Experience is necessary here. Work over the particular ores you come in contact with, until you learn them thoroughly.

### III. CRUCIBLE PROCESS.

This process is the reverse of the scorification method, for here (with one special exception), the object is to secure fusion without oxidation ; in fact, reduction or the removal of oxygen is necessary. Litharge is added to supply lead to extract the precious metals, the oxygen of the litharge being removed by the carbon of charcoal, argol, cream of tartar, etc. Bi-carbonate of soda and carbonate of potash are mixed with the ore to secure fluidity, and they with silica or borax glass form a slag with the gangue of



the ore. All these, or whatever of them are used, are mixed and heated in a crucible till perfect fusion is attained.

The various steps followed are the same as those in the scorification assay, substituting for "scorification," "crucible fusion."

Weigh the requisite amount of ore, sampling as usual. If it is thought desirable, roast, either in the muffle or over the flame of a Bunsen burner. If the quantity taken be over 2 A. T., roast in an ordinary frying-pan over an open fire, having previously coated the interior of the pan with ruddle or chalk.

A good charge for an ordinary silicious ore (quartz, sand, etc.), free from sulphurets and base metals, and commonly called a "dry ore," is :

Bi-carbonate of soda.....	2	A. T.
Carbonate of potash.....	$\frac{1}{2}$	"
Litharge .....	$1\frac{1}{2}$	"
Ore.....	1	"
Borax glass.....	$\frac{1}{5}$	"
Charcoal....	400	mgrams.
Salt cover.		

Weigh out first the carbonates (approximately), and brush into a clean piece of black glazed paper. Next weigh the litharge, then the ore, followed by the charcoal, all three *very carefully*, transfer to the top of the carbonates, add the borax glass and mix everything thoroughly.

Brush the charge into a sand crucible, which it should not more than two-thirds fill (an "S" Battersea crucible is a good size). Tap gently till contents are level, and cover with from one-fourth to one-half inch of dry common salt.

The crucibles used are to be numbered or lettered by means of liquid ruddle, in several places, and in large characters, that there may be no difficulty in identifying them after fusion. This marking may be omitted if the fusions are made in regular order.

Have the fire quite hot, place in it the crucible, covered, bank around it with fuel, and heat till contents are in quiet fusion, which will be in from twenty-five to forty minutes,

according to the temperature of the furnace, nature of the fuel, character of the ore, etc.

When satisfied that the charge is well fused, remove cover, lift out the glowing crucible by means of the long handled crucible tongs (figs. 23 to 26), and tap it gently on a brick three or four times (in order to gather together into one button any little pellets of molten lead that may be scattered throughout the fused mass), then cover and let stand till cold.

Instead of having the fused charge cool in the crucible, it can be poured into the scorification mould which will hold the button and some of the slag ; the excess of the latter can run to waste.

Crucibles that have had their contents poured out can be employed a second time or even more often. In case of ores that have shown little or no gold or silver, this may do, but with ores of any richness, it is a dangerous experiment to re-use their crucibles. Accuracy should never be sacrificed to a spirit of false economy.

Never try to cool a crucible by dipping it into or holding it under cold water, as the but partially cooled lead is liable to separate into globules of various sizes, incurring danger of loss.

When stone-cold, break the crucible or the slag if the charge has been poured, saving a piece of the slag for future examination and comparison. Detach from all adhering slag the lead button and hammer into shape as usual.

If the button is too large, reduce by scorification, cupel, weigh, part, etc., etc., as previously directed.

To consider the charge a little. The litharge is to furnish the lead which is to collect in one button the gold or silver or both, suspected to be in the ore. By the action of heat the carbon of the charcoal (or of argol, cream of tartar, flour, etc., in other cases) takes away the oxygen from the litharge or oxide of lead, leaving it in the metallic state, when it sinks down to the bottom of the crucible, showering

through the ore, and carrying with it the precious metals. The borax glass unites with the gangue of the ore, forming a slag. The carbonates are simply fluxes, that is, aiding the mixed mass to fuse, while the salt cover protects the surface, and washes clean the upper interior of the crucible.

When the crucible is broken, we find then three things: at the bottom the lead button containing the gold and silver, above it the slag, and topping all a layer of fused salt. In other cases, where iron has been employed to take up the sulphur in pyrites of various kinds, there may be found above the lead button, an iron or copper matte.

If it be desired to run a larger amount of ore, say 4 A. T., make the soda in the charge given 4 A. T., and the borax glass  $\frac{1}{2}$  A. T., letting the other ingredients remain the same.

When small amounts of galena or of iron and copper sulphides are present, suspend one or two iron nails in the charge, as in the lead assay.

An ore mainly pyrites may or may not be roasted. In the former case, diminish the charcoal in charge given one-half, for there will still be enough reducing compounds present to bring down a good sized lead button. Also replace the borax glass with 1 A. T. of silica, though even then a little borax sprinkled over the top of the charge will do no harm.

Ricketts recommends the following charge:

Bi-carbonate of soda.....	4	A. T.
Litharge .....	2	"
Ore .....	2	"
Black flux substitute.....	1	"
Silica .....	2	"
Iron wire .....	12	loops
Salt cover.		

If any matte is formed, scorify down with the button.

Mr. A. H. Low, of Argo, Col., has given me a good hint in the crucible running of sulphuret ores which I herewith jot down. Make the fusion in the usual manner, and when it is supposed to be completed, take out, pour off

as much of the slag as possible without losing any of the lead. The button can now be easily seen and if all the sulphur has not been driven off, replace the crucible in the fire *at an angle*, and scorify as it were till the sulphur has gone, take out, pour, and the result will be a clean button.

The same gentleman gives me a charge where the sulphurets are not very abundant :

Bi-carbonate of soda.....	20 grammes.
Litharge .....	50       “
Ore .....	$\frac{1}{2}$ A. T.
Common borax, powdered.....	20 grammes.
Argol .....	4       “
Salt cover.	

For ores richer in sulphurets, add from 1 to 10 grammes of nitre.

In general, for ores carrying copper in large amounts, make the litharge in quantity three times that of the ore.

If the gangue of an ore is lime or baryta, instead of silica, make the borax glass at least one-half as much as the ore taken, and in such

a case it is better to place the glass on the top of the charge rather than to mix it with it.

If tellurides are to be treated by crucible process, use an excess of litharge.

Mr. Geo. L. Stone has published the following as a universal flux for basic silver ores (*i.e.*, those in which the gangue is lime, baryta, etc., for instance the three spars, calc-spar, heavy-spar and fluor-spar) :

Bi-carbonate of soda.....	9 parts.
Borax glass.....	3 “
Argol .....	1 part.

“Mix thoroughly and keep on hand ready for use. For one-third assay ton of ore, fill the crucible about two-thirds full of the flux, adding 2 or 3 iron nails if the ore contains much sulphur.”

From all the preceding, it will be seen how absolutely impossible it is to make a charge for all cases ; the ores must be studied to be properly treated.



## SPECIAL CHARGE FOR GALENA.

Ore.....	1	A. T.
Bi-carbonate of soda.....	2	“
Carbonate of potash.....	$\frac{1}{4}$	“
Nitre.....	$\frac{3}{4}$	“
Salt cover.		

Treat in the usual manner. The action is oxidizing, the nitre furnishing oxygen to a portion of the galena, leaving enough lead behind to retain any silver.

With all ores poor in silver, deduct the silver known to be in the litharge, according to the amount of the latter employed.

## CHAPTER II.

### COPPER ORES.

OCCURRENCE.—Copper is found both native and in combination with many elements, principally with sulphur as a sulphide or sulphuret, with oxygen as an oxide, and with carbon, hydrogen and oxygen as a hydrated carbonate. It has also been discovered associated with most of the metals, common or rare.

It is obtained for the arts and manufactures mostly from the following ores :

1. Native copper (copper, sometimes accompanied by silver), when pure, 100 per cent.
2. Cuprite (red oxide of copper), with 88.8 per cent copper.
3. Melaconite (black oxide of copper), with 79.8 per cent copper.

4. Azurite (blue carbonate of copper), with 55.2 per cent copper.
5. Malachite (green carbonate of copper), with 57.4 per cent copper.
6. Chalcocite (sulphide of copper), with 79.8 per cent copper.
7. Chalcopyrite (sulphide of copper and iron), with 34.6 per cent copper.
8. Tetrahedrite (gray copper ore), copper variable, normally contains about 38 per cent.\*

ASSAY.—Of the many *dry* methods for the testing of copper ores, it may safely be said that no single one is very accurate. The various metallurgical works usually have processes or modifications of processes peculiar to themselves, but which are always more or less imperfect. Many of these processes are complicated, and require great skill with constant practice.

I have then thought it best to specify but

\* See appendix for more extended list of copper minerals.

three assay methods, they being representative ones.

### I. METHOD FOR NATIVE COPPER.

(As a simple mixture of rock and metallic copper.)

Here the only action is fusion.

#### CHARGE.

Ore.....	10 grammes.
Bi-carbonate of soda .....	20     "
Carbonate of potash.....	5     "
Borax glass.....	1     "
Salt and charcoal cover.	

Sample ore as usual. Mix charge and pour in "U" crucible. Put cover of  $\frac{1}{2}$  inch salt and then 1 inch of wood charcoal. Cover and heat intensely for twenty to thirty minutes. After cooling, break crucible and clean button from slag. Multiply weight by ten for percentage of copper.

### II. METHOD FOR OXIDES AND CARBONATES OF COPPER, FREE FROM SULPHUR.

Here the action is reducing, followed by

the collection of the copper globules into one button.

## CHARGE.

Ore.....	10 grammes.
Black flux substitute .....	30      "
Borax glass.....	5      "
Argol .....	2      "
Salt and charcoal cover.	

Use a "U" crucible, chalk-lined. Cover, heat gradually for twenty minutes, then increase to white-heat for forty minutes. Remove, tap and let cool. Results approximate, the error augmenting by the presence of other metals.

### III. METHOD FOR SULPHIDES OF COPPER, WITH ARSENIC, ANTIMONY, ETC.

The first step, roasting, is to drive off the sulphur and the volatile metals, arsenic, antimony, zinc, etc., converting the copper into an oxide. The second operation is reduction to the metallic state, and the third the fusion together of the copper with metallic lead reduced from litharge.

## CHARGE (RICKETTS).

Ore (roasted after weighing).....	10	grammes.
Black flux substitute.....	25	"
Litharge .....	6	"
Borax glass.....	5	"
Argol .....	2	"
Salt and charcoal cover.		

Chalk-lined "U" crucible. Heat for twenty minutes.

The button of copper and lead must be refined to be freed from the latter metal. Place in a large cupel, already well heated, in the muffle, and let it there remain till "brightening" occurs, indicated by a peculiar green color. As soon as this has happened, cover cupel with coke or coal-dust, take out and cool in water.

The greater part of the lead will have been oxidized and have volatilized or have been absorbed into the cupel. Results moderately accurate, as a portion of the copper will have oxidized, or the button may still carry lead.

(Read Mitchell, and Bodeman and Kerl, on "Copper Assays.")

## CHAPTER III.

### LEAD ORES.

OCCURRENCE.—Lead is very rarely found native (that is, as the pure metal), but occurs combined with various elements, as antimony, arsenic, carbon, chlorine, chromium, molybdenum, oxygen, phosphorus, selenium, sulphur, tellurium, tungsten, vanadium, etc. Combinations of some of the above elements with each other and with lead exist, either alone or associated with such metals as cobalt, copper, gold, iron, mercury, nickel, silver, zinc, etc.

Many of these compounds are merely mineralogical curiosities, and will not be considered here.

The *important workable* ores are the following :

1. Galenite (galena, sulphide or sulphuret of lead), when *pure* consisting of 86.61 per cent lead and 13.39 per cent sulphur.

2. Cerussite (white lead ore, carbonate of lead), containing 77.52 per cent lead.
3. Minium (red oxide), with 90.80 per cent lead.\*

ASSAY.—The method of assaying a lead ore depends upon the nature of the ore.

#### 1. METHODS FOR GALENA.

(Also for selenides, sulphates, and for galena containing antimony and arsenic.)

##### *A. By Crucible Fusion in Furnace.*

1. With bi-carbonate of soda and metallic iron.

#### CHARGE.

Ore.....	10 grammes.
Bi-carbonate of soda.....	25       “
Carbonate of potash.....	10       “
3 iron nails or	
3 loops of iron wire.	
Salt cover.	

Prepare the sample according to the directions given on pp. 133-138.

\* For more complete list of lead minerals see appendix.



Weigh first the carbonates, then the finely pulverized ore, and mix thoroughly on glazed paper.

(Read the notes on the "Crucible Assay of Gold and Silver Ores," p. 170.)

Brush into a lettered or numbered\* small sand crucible (size "U" of Battersea make), and settle contents down.

If there is considerable pyrites in the ore, sprinkle now over the surface of the charge one gramme of finely powdered borax glass.

The three iron nails (eight-penny) are to be held together by their heads with iron wire (No. 16), and then inserted, points down, in the crucible, leaving a loop of the wire hanging over the edge that the nails may be easily and quickly withdrawn when the operation is concluded. If wire only is used, bend a piece of the No. 16, about six inches in length, in the form of a horse-shoe with a loop above, and in the loop hang two smaller pieces bent in the form of hair-pins; let all six points be about on a level. Insert into the charge.

Finally pack on the surface of the charge and around the nails or wire one-half inch of dry salt.

Place the crucible in a moderately hot fire, *cover* and surround with coke.

This process will require twelve to fourteen minutes.

When fusion is complete, take off the cover, remove crucible from fire, then by means of small tongs stir the nails or wire loops around in the molten mass once or twice, and *while in the hot fluid* tap them against the side of the crucible, then withdraw them, tap gently the crucible and cover. All this should be done as rapidly as possible.

When cold, break and hammer lead into shape as usual.

The weight of the button, multiplied by ten, will give the percentage of metallic lead in the ore.

*Tests of Good Work.*—After fusion the interior of the crucible should be smooth and have no half-fused portions adhering to the

sides. The charge should be well settled to the bottom and have an even surface. The slag should be uniform in character, and of a purplish-black color. The lead should be at the bottom in *one* button, and be perfectly malleable. A glistening button indicates undecomposed galena; a brittle one the presence of antimony, arsenic or iron.

The alkaline carbonates act mainly as fluxes, but a portion of the lead they convert into a double sulphide of lead and soda (or potash), which the iron desulphurizes, forming sulphide of iron and metallic lead.

In order to learn the proper running of this lead assay, it will be well for the student to perform it at least *ten* times on the same ore.

2. With black flux substitute and metallic iron.

## CHARGE

Ore ..... 10 grammes.

Black flux substitute.....35       “

3 iron nails or

3 loops of iron wire.

Salt cover.

Treat in same manner as for the first method. Let remain in fire twelve or thirteen minutes.

Add one gramme of borax glass to pyritic ores.

The carbon of the flour of the black flux substitute exerts an additional reducing action.

Perform this assay a number of times for practice.

The remarks given under the first method are applicable here.

### 3. With cyanide of potash.

#### CHARGE.

Ore ..... 10 grammes.

Cyanide of potash..... 30     “

Salt cover.

Time in furnace, about fourteen minutes.  
Cover as usual.

In this process the sulphur of the ore unites with the cyanide of potash, making the latter a sulpho-cyanide.

Half-a-dozen runnings will be sufficient for this method.

These three methods can be performed with satisfaction in Fletcher's gas furnace (p. 45).

*B. By Crucible Fusion in Muffle.*

4. With bi-carbonate of soda and argol (Ricketts).

CHARGE.

Ore.....	10 grammes
Bi-carbonate of soda.....	20     "
Argol.....	5     "
Flour.....	2     "
Borax glass.....	1     "
2 loops of iron wire.	
Salt cover.	

Mix the ore, soda, argol and flour, and pour into a small sand crucible large enough to stand in the muffle used. Sprinkle over the charge the fine borax glass, insert two pieces of iron wire bent as hair-pins, and tamp down with from  $\frac{1}{4}$  to  $\frac{1}{2}$  inch dry salt. Use no cover.

Have the muffle at a bright red heat, and place the crucible or crucibles therein; after

about ten minutes of good heat, increase the temperature for twenty-five minutes longer, when the contents of the crucibles should be in perfect fusion.

Take out, remove wires, tap, and let stand covered till cool, do not pour, break, hammer button, etc.

The size of the crucibles used will depend upon the height of the interior of the muffle, and the fact that the muffles usually employed are small very often either necessitates a smaller charge, or renders it impossible to use this process.

For this work, one may either use the very small crucibles of the ordinary form, surrounding each crucible with a little cup or platform of fire-clay and sand mixed up with borax water, that it may stand securely in the muffle, or the special form for muffle fusions shown in fig. 46. The latter is recommended.

### *C. By Fusion in Scorifiers.*

This is a modification of the lead assay.

designed to be used where the muffles are not large enough to admit of crucibles.

It is simply a substitution of scorifiers for crucibles, using the same charges (reduced one-half in quantity) as for crucible work, and employing the muffle.

I have had good success with the third charge, employing half the respective amounts, thus :

#### 5. With cyanide of potash.

##### CHARGE.

Ore.....	5 grammes.
Cyanide of potash.....	15       “
Salt cover.	

For a “J” Battersea muffle, employ a  $3\frac{1}{2}$  inch Battersea scorifier. Have the muffle red hot, introduce scorifier, cover with  $3\frac{1}{2}$  inch circular crucible cover (“G” of Battersea), heat moderately for ten minutes, then intensely for twenty. Remove cover, take out scorifier, do not pour but let cool covered, break, and shape lead button. Multiply weight by twenty for percentage.

*Comparison of Processes.*—The cyanide of potash process in crucibles gives the highest results, the buttons are clean and malleable, and the slags almost always uniform. I have found it the one most quickly learned, and so, on all accounts, I give it the preference.

The fourth process (crucible in muffle) comes next in percentage of lead obtained.

The second process (black flux substitute) ranges next, and is quite satisfactory to work.

Very close in results to the preceding, is the third process in scorifiers (No. 5, half charge).

The first process (bi-carbonate of soda) gives lower results than any of the others.

A method with ferrocyanide of potash, that is sometimes used, I have omitted entirely, on account of its inaccuracy.

## II. METHODS FOR OXIDES AND CARBONATES.

(Cerussite, minium, etc.)

By crucible fusion in or out of muffle.

6. With soda, potash and argol.



## CHARGE.

Ore.....	10 grammes.
Bi-carbonate of soda.....	15 “
Carbonate of potash.....	5 “
Argol .....	5 “
Salt cover.	

Mix as usual, and transfer to small crucible. Cover, if fusion is made in the open fire, but not if the muffle is used. Heat gradually for about fifteen minutes, then somewhat more strongly till fusion ensues. Take out, pour or not, as desired. Cover if left in crucible to cool.

Action reducing—the oxygen of the ore is seized by the carbon of the argol, leaving metallic lead.

### 7. With soda, argol and borax.

Prepare a flux, in quantity, of the following ingredients :

## CHARGE.

- 2 parts bi-carbonate of soda.
- 2 parts argol.
- 1 part common borax, in powder.
- 1 part flour.

Have the above well mixed, then sifted, and keep ready for use.

Fill about two-thirds full a so-called "5 gramme" crucible (page 71), with the above flux, add 5 grammes of the ore, and mix in crucible. Put in muffle without cover. Keep the heat as low as possible, without letting it get too cold.

If the ore shows sulphurets, put in a nail or two.

If the ore is quite calcic or barytic, make the borax  $1\frac{1}{2}$  parts and the flour  $\frac{3}{4}$  of a part.

For ores containing much manganese, add to flux a little more borax and flour.

*Concluding remarks.*—At the best, the assay of lead ores is inaccurate, mainly on account of the volatility of the lead itself, though in the case of galenite ores, it is supposed that the galena begins to sublime before the decomposition is effected.

Also, the lead button is liable to contain antimony, iron, and zinc from the ore, or iron

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from the nails, wire, or iron salts employed in the assay.

Try then to avoid an unnecessarily high heat, remove assays as soon as fusion is obtained, and use covers as much as possible.

See Mitchell, 5th ed., pp. 443-477 inclusive.



## APPENDIX.



## SECTION I.

### SPECIAL METHODS.

#### I. ASSAYING OF THE VARIOUS MINERALS CONTAINED IN AN ORE.

It is sometimes desirable to know *where* the gold and silver are located in an ore, that is, which minerals carry them to the greater extent. This can not always be done, for the various minerals may be so thoroughly commingled that separation will be impossible. But in other cases, it can be done with success. For example, an ore is found to be made up of three distinct minerals, blende, galena and pyrites in a quartz gangue. Weigh the piece selected, and crush roughly in a mortar, taking care not to lose any, and pour out on a clean surface, as a sheet of white paper. With a pair of pincers pick out such pieces of the quartz as show none of the min-

erals mentioned, and reject them. Then it will be comparatively easy to put aside, in three piles, the minerals, each quite free from the other two. By carefully crushing the remaining mixed pieces, the entire lump will finally be separated into its three component valuable minerals and the worthless gangue.

Weigh each lot, and assay the whole of each or fractions thereof.

To show method of calculation, I give the following

EXAMPLE.

Weight of sample of ore, 500 grammes,

Which was composed of:

Pyrites,	40 grammes.
Blende,	60       “
Galena,	100       “
Quartz gangue,	300       “
<hr/>	
500 grammes.	

$$\text{Percentage of pyrites} = \frac{40}{500} \times 100 = 8$$

$$\text{“ “ blende} = \frac{60}{500} \times 100 = 12$$

$$\text{“ “ galena} = \frac{100}{500} \times 100 = 20$$

$$\text{“ “ quartz} = \frac{300}{500} \times 100 = 60$$

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100



Pyrites.—The 40 grms gave 10 mgrms gold—no silver:

$$\frac{10}{500} \times 29.166 = 0.58332 = \frac{58}{1000} \text{ of an ounce per ton.}$$

Blende.—10 grms gave 4 mgrms silver—no gold:  $4 \times 6$

$$= 24; \frac{24}{500} \times 29.166 = 1.39 \text{ oz. silver per ton.}$$

Galena.—20 grms gave 160 mgrms silver—trace of gold:

$$160 \times 5 = 800; \frac{800}{500} \times 29.166 = 46.6 \text{ oz. silver per ton.}$$

## II. ASSAYING OF ORES CONTAINING FREE GOLD OR FREE SILVER.

The average ore does not carry the precious metals in the free state. But when they are present in such form, proceed as follows:

Crush the sample selected, having first weighed it. Pulverize as usual, and sift, using the box sieve. As a result we shall have two things, the finely powdered siftings below and more or less free metal in scales on the sieve.

Weigh the scales, and, as a check, the siftings. The weight of the latter should be but a trifle less than the difference between the original weight and that of the scales, if care has been taken in pulverizing.

If not too large an amount, *all* the scales

should be wrapped in pure lead-foil, and cupelled directly. If quite an amount be present, simply scorify down in the usual manner.

Take a weighed fraction (one-half, one-tenth, one-twentieth, as the case may be) of the siftings, and assay by scorification or crucible process. The number of milligrammes gold and silver obtained are each to be multiplied by the proper fraction to ascertain the amounts present in the entire bulk of the siftings. Add the gold thus calculated to be in the whole of the siftings to the amount found to be in the scales, and the same with the silver. If the metal is all free gold or all free silver, the calculations are still simpler.

To make this matter perfectly clear to those who may still be puzzled, I illustrate by an example as given by Prof. Ricketts in his "Notes on Assaying":

"The sample presented for assay weighs 485 grms. Pulverized and sifted in a box sieve it gave:

- A. Sifted ore ..... 480 grms.  
 B. Metallic scales ..... 5 “

A. SIFTED ORE.—10 grms. gave by crucible assay :

- Gold ..... 4 mgrms.  
 Silver, after deduction of the silver in the litharge ..... 14.3 “

Hence, the total precious metal in the siftings is :

- Gold .....  $\frac{4.00}{10} \times 480 = 192.0$  mgrms.  
 Silver .....  $\frac{14.30}{10} \times 480 = 686.4$  “

B. METALLIC SCALES.—These melted with lead gave a button of, say 60 grms., which was rolled out and 10 grms. taken for cupellation, which yielded :

- Gold ..... 2.6 mgrms.  
 Silver ..... 500.0 “

Hence, the total precious metals in residue must be :

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Gold .....  $\frac{2.6}{10} \times 60 = 15.60$  mgrms.

Silver .....  $\frac{50.0}{10} \times 60 = 3000.00$  “

Total :

Gold in siftings ..... 192.00 “

“ “ residue ..... 15.60 “

Gold in ore taken ..... 207.60 “

Hence :

$\frac{207.60}{485} \times 29.166$  (value of an assay ton) = gold  
per assay ton of original ore.

Silver in total siftings ..... 686.40 mgrms.

“ “ residue ..... 3000.00 “

“ “ ore taken ..... 3686.40 “

Hence :

$\frac{3686.40}{485} \times 29.166$  (value of an assay ton) =  
silver per assay ton of original ore.”

On this same matter of the calculations of the value of an ore containing free gold or silver, I append an article contributed by Mr. F. A. Lowe to the “Engineering and Mining Journal” (Vol. xxxiii, No. 6, Feb. 11, 1882, p. 81):

## "METALLIC SCALES.

In using the metric system in assaying ores carrying native silver or metallic scales, the following method will be found to be simple and expeditious. It is based upon the value, per ton, in ounces, of 1 milligram of metallic scales in 1 gram of ore = 29.166 per ton.

To find approximately the metallic scales, per ton, from any amount of ore taken as a sample, divide the whole weight of the sample taken into 29.166, and multiply the quotient by the weight (in milligrams) of the metallic scales cupelled.

## EXAMPLE.

Weight of sample taken, 400 grams.

$$29.166 \div 400 = 0.07291$$

Assay value of siftings per ton . . . . . 300.00 ounces.

Weight of metallic scales cupelled = 500

milligrams; hence  $500 \times 0.07291 = \underline{34.45}$  "

Total value per ton of such samples . . . 334.45 "

As 100 grams from any well-sampled sample is the most convenient amount on which to base the approximate value per ton, by

simply dividing the weight, in milligrams, of the metallic scales cupelled, by 3.427, and adding the quotient to the assay value of the siftings, the same result will be obtained as when 100 grams is multiplied by 0.29166, and the result added to the siftings.

EXAMPLE.—FIRST METHOD.

Weight of sample, 100 grams.

$$29.166 \div 100 = 0.29166$$

Assay value of siftings per ton 200.0 ounces.

Weight of metallic scales cupelled = 500

milligrams; hence  $500 \times 0.29166 = \dots 145.8$  “

Total value per ton of such samples  $\dots 345.8$  “

SECOND METHOD.

Weight of sample, 100 grams.

Assay value of siftings per ton  $\dots\dots\dots 200.0$  ounces

Weight of metallic scales cupelled = 500 “

milligrams; hence  $500 \div 3.427 = \dots\dots 145.8$

Total value per ton of such samples  $\dots 345.8$  “

3.427 is the weight, in milligrams, of metallic scales, corresponding to 1 ounce per ton, obtained from 100 grams as a sample. To

determine approximately the whole amount of silver, in milligrams, in a sample, divide the assay amount, usually  $\frac{1}{10}$  assay ton for silver ores, into the whole weight of sample minus weight of metallic scales cupelled, and multiply the quotient by the weight of button obtained from the siftings; then add weight of metallic scales cupelled.

## EXAMPLE.

	MILLIGRAMS.
Weight of sample, 1 kilogram .....	= 1,000,000
Weight of metallic scales cupelled .....	1,000
$1,000,000 - 1000 \div 2916$ .....	= 342.5
Weight of button obtained from 0.1 assay ton .....	50
Then $342.5 \times 50$ = total amount of silver in the siftings .....	= 17,125
Total amount of silver in the sample, 17,125 + 1000 .....	= 18,125
or .58 ounce troy.	

Remembering that 31.17 grams equal 1 ounce troy, and 28.40 grams equal 1 ounce avoirdupois, any weight avoirdupois can be easily reduced to the metrical system and the whole amount of silver to troy ounces."

## III. ANALYSIS OF COPPER ORES.

The *wet* process or analysis of copper ores is so much more accurate than the *dry* process or assay, that it should always be employed when practicable.

As in the assay of copper, so in the analysis, there are many methods, here included under three heads; volumetry, gravimetry and electrolysis. While there are good ways of determination among the first two classes, yet I prefer one in the third, owing to its simplicity, accuracy, freedom from intricate calculation, and the ease with which it can be acquired.

The process I now describe is known as the *Luckow method*, and consists, briefly defined, in dissolving the copper out of its combinations by means of acids, and then depositing it as the metal itself upon another metal, platinum, by the action of an electric current.

It makes no difference whatever in this method, how the copper is originally combined, whether as a sulphide or in a mixture



of sulphides of other metals, an oxide or carbonate, a matte or an alloy; the copper comes out as metallic copper in any case.\*

#### PROCESS.

Prepare the sample in the usual manner, being sure to use a 100-mesh sieve. Sample and weigh out very carefully on the ore scales, one gramme, if the ore be at all rich (say above 20 per cent), or five grammes if it be poor in copper (below 20 per cent).

Brush into a casserole, *i.e.*, a porcelain evaporating dish with a handle (fig. 58), and cover with a clock-glass (fig. 52), of slightly larger dimensions, and add 10 cubic centimetres of pure and concentrated nitric acid, by means of a 10 c.c. pipette (fig. 59).

Now place the casserole either on a sand-bath (a common tin plate holding some dry

\* If accessible, consult a very interesting paper, entitled "Comparison of Various Methods of Copper Analysis," by Mr. W. E. C. Eustis of Boston, which was read at the August, 1882, meeting in Colorado of the American Institute of Mining Engineers, and is to be found among the published transactions of that society.

sand), or on a piece of wire gauze, supporting either on a ring-stand (fig. 63), and heat with a Bunsen burner (fig. 64), or alcohol lamp. Continue this heating some little time, then let cool. When cold, add, from another pipette, 5 c.c. of pure and concentrated sulphuric acid, and heat to boiling till no more *red* fumes are given off, but in their stead dense *white* vapors are delivered.

The red fumes are from the nitric acid, the excess of which we wish to get rid of, which is done by means of the sulphuric acid, and the white fumes show that the former acid is about gone. Let the casserole stand till cold.

Now add about 50 c.c. of distilled water, stir with a glass stirring rod, heat, and let stand till any undissolved matters have settled to the bottom of the casserole.

While this is doing, prepare for filtering, that is the separating of the dissolved copper (and other metals) from the undissolved silica, etc. Place in proper position a filter-stand (fig. 68), glass funnel (fig. 57), and

glass beaker (fig. 56). The filter-paper is fitted by cutting a piece in a square, then folding in half, diagonally, and then into quarters ; it will form a triangular figure, and if the corners are cut off in a curved line, a circle will be formed on spreading out. Upon opening the folded paper so that three thicknesses come on one side and one on the other, a filter is obtained, which is placed in the funnel and wetted by means of the wash-bottle (fig. 51). This useful piece of apparatus is operated by simply blowing in at *a* ; a fine stream of water at once issues from *b*, which can be directed against any part of the funnel.

Filter the liquid in the casserole by holding the glass-rod outside the lip of the vessel, allowing the solution to run down the rod into the funnel, till the latter is nearly full. Repeat the operation until nearly all the solution has passed through the funnel, and the sediment (if there is any) begins to flow over. Examine the residue, and if it is dark-colored, it is best to repeat the treatment with acids.

Generally, however, once is enough. Finally wash the contents of the casserole into the funnel, which fill three or four times with water, which will be sufficient to wash out all the copper solution.

The residue on the filter-paper consists of silica and other substances insoluble in the acids used. It should contain no copper.

The filtrate, that is the filtered liquid, contains the copper as sulphate (with perhaps some nitrate), also it may be, iron, lead, etc., but these do no harm.

The next thing is to deposit the copper upon platinum. We may use a vessel entirely of platinum, or a copper dish lined with platinum, or a horseshoe shaped strip of platinum suspended in a glass beaker. In case the operator possesses the platinum or platinum-lined dish, clean it thoroughly by washing. If it is a new vessel, best rinse it first with some solution of caustic soda or potash to remove grease, then rub it gently with a little *fine* sand, thus giving the interior a surface favor-

able for deposition. Be sure to wash off all the soda or potash solution and sand, then warm till it is perfectly dry. When cool, weigh carefully on the ore scales and note the weight. Pour the copper solution into the platinum dish, using the glass-rod, which rinse off with water into the dish; finally rinse out the beaker with a little water into the dish.

We now have a weighed dish containing copper in solution from a known weight of ore. It remains to connect it with a battery, which latter is now described.

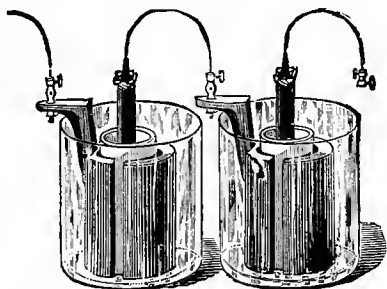


FIG. 71.

Fig. 71 represents two cells of what is commonly known as the "Bunsen Carbon," which

form a battery powerful enough for our purpose. A quart size will be about right. It consists of a glass cell or jar to contain the dilute sulphuric acid, a cylinder of cast-zinc, of which the ends do not quite meet; a porous earthenware cup, to hold nitric acid, and a rod of compressed carbon.

Prepare a mixture of strong sulphuric acid (ordinary commercial) and water in the proportion of one part of the former to ten of the latter, observing the precaution of pouring the acid into the water, never the reverse. Let the zincs stand in this acid solution for two or three minutes, then pour over them a little mercury, and rub with a piece of soft rag tied around a stick, till the entire surface, inner and outer, of the zincs, is coated with amalgam.

Put each cell properly together and fill the glass jars with the sulphuric acid mixture, just covering the tops of the zincs. Next, nearly fill the porous cells with concentrated (com-

mercial) nitric acid. \* See that the binding screws are filed bright, also the connecting wires, to make good contact. Arrange apparatus as follows :

The zinc of the first cell is to be united with the platinum dish by means of a coil of copper wire underneath the latter. A strip of platinum foil (cleaned with potash solution and sand) just dips into the solution of copper, and is connected to the carbon of the second cell by a copper wire. Another wire between the zinc of this latter cell and the carbon of the first, completes the circuit. Cover the dish with two pieces of window-glass, to prevent loss by spattering.

The copper at once begins to line the interior of the dish, and in from four to six hours the deposition will generally be complete. Time is often gained by starting the action at evening, and letting it run all night.

Prove the complete deposition of the cop-

\* A bench of from two to six so-called "gravity" cells will do instead of the pair of Bunsen Carbons, and are more constant.

per by taking one drop of the solution and adding to it one drop of sulphuretted hydrogen water, mixing the two on a white surface (cover of a porcelain capsule). If no coloration ensues, the copper has all been thrown down; if a black discoloration follows, then there is still copper in solution. In this latter case, continue the current till the test is negative.

In the former case, pour the contents of the dish into a clean beaker, rinse the dish, the under surfaces of the glass plates and the platinum strip, into the same beaker. On adding to the contents of this beaker an excess of aqua ammonia, no *blue* coloration should be seen.

Add a few drops of alcohol to the dish, rinse around and drain off. Set fire to the little remaining in the dish, and when the latter is cool, weigh. The difference between this latter weight and the original weight of the dish is metallic copper. I give an example :



Weight of ore taken = 1 gramme.

Weight of platinum dish and copper = 56.408

GRAMMES.

“ “ “ “ empty = 55.659

“ “ copper from 1 gramme = 0.749

0.749 multiplied by 100, gives 74.9 per cent  
of metallic copper in the ore.

As before mentioned, instead of the platinum dish, which is quite expensive, a glass beaker can be used to contain the copper solution. A second platinum strip, on which is to be deposited the copper, must be used here. Dip this in the beaker and connect with a zinc element. The platinum strip in straight form connects with the other carbon as usual.

If the copper should form dark colored on the platinum, it is because the solution is too acid. *Nearly* neutralize with a little ammonia water, to counteract its bad effect. Too strong a current should also be avoided. I have given this process well in detail, but it will be found to be much easier learned than described. It is a very pretty and satisfactory method.

*Volumetric analysis of copper ores.*

If very many tests of copper ores, slags, mattes, etc., are to be made daily, the volumetric process would best be used, for while it is not so accurate as the battery process above described, it is much more rapid.

Make a solution of the copper, as though it were to be determined by battery process, using one gramme of ore.

It is the safest plan to remove the copper from all other metals present, by adding to the diluted sulphuric acid solution, say three grammes of pure metallic zinc. In about fifteen minutes all the copper is precipitated. (Make sure of this by pouring solution into a platinum dish and adding sulphuric acid and zinc. If no copper shows on platinum after a minute or so, the precipitation is complete.) Now add a large excess of sulphuric acid to solution in beaker to dissolve the excess of zinc. Pour off liquid, wash copper with water, and re-dissolve in nitric acid.

Add ammonia water till solution is deep

blue and titrate with cyanide of potassium solution.

Consult authorities on volumetric analysis.

#### IV. AMALGAMATION ASSAY OR LABORATORY MILL RUN.

By M. G. NIXON, M.E.

The wet copper assay bears somewhat the relation to the fire copper assay that the fire gold assay does to the amalgamation gold assay.

In a certain sense, no one cares to know the ultimate amount of metal that an ore contains. What is desired in practice, is the *yield* under the most skilful treatment, and this information is approximately obtained by fire for copper, and the amalgamation process for gold.

There are those so practised in "panning," that from a "panful" of "pulp" they can very closely guess the yield by the number of "colors" and their size. Of course this method is not very popular, nor can it ever be.

Something more a matter of weighing, and less a matter of judgment and practice is required.

The amalgamation assay in its simplest form consists in "panning" a weighed amount of "pulp" with few or many drops of mercury, accordingly as the ore is poor or rich. The tailings are washed out as clean as may be, the pan is then placed over a fire to dry and then what remains of dirt and dust is blown out with the breath; the pan is again placed over the fire and the mercury volatilized, leaving the gold ("retort") ready for weighing. This process is quite largely followed by prospectors in some of our free-gold districts.

An improvement on the method just described consists in grinding the pulverized ore in a large iron mortar with which water and mercury are introduced, with the pestle. When the grinding is complete, the whole is washed into a pan to be collected and finished as before.

These methods are not recommended, but

may be resorted to when other apparatus can not be obtained.

The third method consists in grinding say ten or twenty pounds of ore in a laboratory "arrastre" by hand two hours or more, or, where possible, by power half as long. It is well to pass the ore through a 40-mesh sieve before placing it in the "arrastre." From two to four ounces of mercury are then squeezed through a piece of chamois skin, or blown through a tube the end of which is drawn out so as to make a pin-hole exit. Having put the pulp and mercury into the "arrastre" mortar, a piece of potassium cyanide as large as the end of one's little finger is dropped in, the grinder adjusted, enough water added to cover the ore, and the grinding performed. After it is finished, the grinder is first washed off into a collecting pan, then the mortar with its contents is treated in the same manner. The best way to collect the amalgam is to hold the pan under a running stream or water faucet, and

very gently to stir it with the hand. The amalgam is then placed in chamois skin and squeezed so as to get rid of as much mercury as possible.

The residue is next placed in a small iron retort, and what remains of the mercury is driven off by heat gradually increased. Of course, for reasons of economy, it is well to condense the mercury; it may then be sold to mills or others, but neither that portion condensed nor that squeezed through the chamois should be used over again, since it is almost impossible to get rid of the last traces of gold. The "retort" is then to be scorified, cupelled, inquarted, etc., etc.\*

The writer has saved 93 per cent of the fire

\*An amalgam obtained as a result from either the preceding method, from panning with mercury, or from any other process, can be treated in the following manner, provided it is not in too great quantity.

Into a new scorifier (say  $2\frac{3}{4}$  inches in diameter) introduce the amalgam after it has been separated from the free mercury by squeezing in a piece of chamois skin. On top of the scorifier place another of same size, *inverted*, having first bored through it a hole about  $\frac{1}{8}$  inch in diameter. By rubbing down a little the tops of the scorifiers, and painting their edges with a thick wash

assay on the same ore that a mill at the time under his superintendence returned 89 per cent.

#### V. PAN TEST FOR GOLD.

("PANNING.")

The estimation of gold in ores in which the metal is in the *free state* is unreliable by

of ground chalk and water, all danger of loss of amalgam by its spirting through at the sides, is avoided.

Heat in muffle or furnace till the mercury has been driven off in vapor through the fine opening above, take out, let cool and remove the upper scorifier.

Now put the chamois skin on top of the residue in the scorifier and burn to ashes in muffle or furnace, remove a second time and cool.

Finally mix the residue and ashes with granulated lead and scorify. Re-scorify with more lead if the resulting button is brittle. Cupel in the usual manner and treat the bead obtained as gold bullion.

If it is not thought worth while to save the mercury, the fluid amalgam can be treated directly as described without first squeezing through a chamois skin, in which case the accompanying step of burning the latter, etc., is dispensed with. Heat very gradually. Even with this apparatus the mercury can be saved by attaching to the upper scorifier a small iron tube which bends over and dips into water.

The advantages of the above method are that it is simple, easy to operate, and that all the work (up to the cupellation) is done in one vessel, and so any liability to loss of gold in transferring from a retort, etc., is done away with. Furthermore, working with small quantities of amalgam, in even the smallest retort obtainable, is unsatisfactory.—W. L. B.

either the crucible or scorification process, owing to the impossibility of securing an average sample.

The ore, for supposition, may be of such value that even when put through a 100-mesh sieve one flake that would go through such a mesh could represent the amount of gold in two assay tons.

If then of two assay tons of ore of the above character, one is taken, it must run either nothing or double the true value of the ore.

Again, on low grade ores and with the charge most convenient to employ, the result or weighable button is so small that its estimation is liable to error.

Many ores containing small quantities of gold are frequently profitable to work, as in the case of placers and of large quartz ledges where the rock is soft and gold free. In such cases the assay report based upon the *small quantity* of ore used in the scorification, or even in the crucible assay, is unsatisfactory for this and the previous reasons.



Here, then, we resort to the pan test, for by it we can treat large amounts of ore, and the greater the quantity operated upon the more reliable the result.

The pan test is a process of concentration (doing on a small scale that which concentrators effect on the large), the product being either gold particles, or gold sulphurets, iron, sand, etc., depending on how far the process is carried.

The pan itself is a Russia sheet iron vessel of a shallow truncated conical shape (diameter about  $16\frac{1}{2}$  inches). That form sold by mining outfit establishments has been found most useful in practical operations. A round shallow wooden dish with its bottom sloping to a point, and technically known as a "Batea," is a useful modification (fig. 48 of Atwood; size of batea: diameter, 17 inches; depth,  $1\frac{7}{8}$  inches; thickness,  $\frac{5}{8}$  inch; angle of sides,  $12^{\circ}$ ; material, Honduras mahogany). Each person will exercise his own choice after learning the operation. After the requisite

skill has been acquired, a pan can be extemporized from almost any kind of dish, or a section of bullock's horn or an iron spoon may serve as substitutes.

The requisite amount of ore from 100 to 500 assay tons (5 to 25 pounds, or in French weights 3 to 15 kilos), depending upon its richness, is sampled, crushed and pulverized as directed in the chapter on gold and silver ore. The pulverization, however, need be carried no finer than to cause the ore to pass through a 40, 50 or 60 mesh sieve (the latter preferred). Weigh now the ore and put in the pan, which latter must be free from grease. Moisten and let it stand for a few moments in order that particles may not float off when the pan is put in water.

When wet, the whole pan and ore is gently sunk below the surface of a tank of water (a common wash tub will do nicely in the laboratory). A peculiar oscillatory motion or side vibration is commenced, though not enough to throw any particles of ore over the edges

of the pan. The object of this is to settle the heavier particles (the free gold, heavy minerals, black sand, etc.), and have nothing on the surface but rock or quartz; a little experience will teach the point. Then slightly incline the pan, and so wash it around as to carry the surface rock over the edge; only a little at a time, however.

Level the pan and resettle as at first; again incline and wash more over the edge. Keep up this operation, gradually getting more and more rock over the edge, and becoming more careful and washing more delicately as the process continues.

Toward the end of the operation, that is, when the rock is nearly gone, be careful to keep the ore under the surface of the water, as the gold might otherwise become dry and float off. Also make no sudden or unusual lurch, or the whole result may go off the pan. The above manipulation is far more difficult to describe than to perform after having once been acquired. Dry the residue.

If gold alone is obtained, that is, gold (or gold and silver) free from sulphurets, etc., it must be treated as an alloy, weighed, parted and weighed again, or cupelled with lead, weighed, parted and weighed; in both cases giving gold and silver.

If the panning is not carried to such a point as to get rid of all the rock, the concentration is all scorified with test lead (or run down in a crucible), cupelled, parted and weighed. In the case of an ore supposed to carry auriferous sulphurets it should be panned so far as can safely be done without losing metalliferous particles and the concentration treated as above described.

If the ore is quite poor, or a large quantity is desired to be worked, the panning can be carried on roughly and the successive concentrations finally panned together.

The results are based upon the amount of ore taken in the pan. If much of this work was to be done, a set of weights from 500 A. T. down (approximately accurate) would

be very convenient and save calculation. The result would be as many times the number of ounces contained in the ore as the quantity of ore was more than one assay ton.

For example, the ore was supposed to be very poor and therefore :

500 A. T. were taken.

Bead weighed 50 mgrms.

$\therefore 500 \text{ A. T.} : 1 \text{ A. T.} :: 50 \text{ mgrms.} : \frac{1}{10} \text{ mgrm.,}$

or the ore ran  $\frac{1}{10}$  oz. Troy per ton.

If 100 A. T. had been taken and the same weight bead obtained, we would have :

$100 \text{ A. T.} : 1 \text{ A. T.} :: 50 \text{ mgrms.} : \frac{1}{2} \text{ mgrm.,}$

or the ore would run  $\frac{1}{2}$  oz. Troy per ton.

As an example of the calculation required *without* the large assay ton weights, I give the following :

Weight of panful of ore,  $2\frac{1}{4}$  kilogrammes = 2,250,000 milligrammes.

Weight of bead obtained, gold 20 mgrs., silver 50 mgrs.,

then  $\frac{2,250,000 \text{ mgrms.}}{20 \text{ mgrms.}} :: \frac{29166}{x} \times = \frac{25}{100} \text{ oz.,}$

and  $\frac{2,250,000 \text{ mgrms.}}{50 \text{ mgrms.}} :: \frac{29166}{x} \times = \frac{64}{100} \text{ oz.}$

The free gold can be separated from the

sulphurets (if it be desired to determine how much of the gold is "free" and how much in the "sulphurets") by washing in an amalgamated pan. Such a vessel may be simply made by bending a piece of thin silver-plated copper (about 6 inches by 12 inches) so as to form curved edges on three sides, the silvered sides in. The side not turned up is one of the narrow ends. A little mercury (free from gold and silver) will quickly amalgamate the interior, and if the ore is washed carefully over this, most of the free gold will become amalgamated and stick to the pan. A piece of chamois skin made into a rubber will push the gold, which can be seen as little specks of amalgam, to the open edge of the pan and into a crucible. The mercury can be driven from the gold by heat.

No investigation has been made to determine if any silver is carried by the mercury to the assay from the pan, but if such be the fact, the result is still accurate for gold. If carefully performed the results ought to be

above the yield from a stamp-mill with amalgamated plates.

A more common test than with the above silver-plated amalgamated copper pan, is, after having panned down, to drop a few globules of clean "quicksilver" (*i.e.*, mercury) into the pan and a little cyanide of potassium (to keep the mercury clean). Work up with a spatula till the mercury has taken up the free gold, then collect, and run off the mercury. Clean it and dissolve in nitric acid (for the gold only) or drive off the mercury in the muffle, weigh the residue of gold and silver, part and weigh gold.

The residue in the pan should then be assayed and the gold and silver (actual weight) determined. Suppose

Original weight of ore.....	2½ kilos.
Gold and silver after retorting.....	35 mgrms.
Gold after parting.....	15 "
<hr/>	
Hence silver .....	20 mgrms.
Gold in sulphurets.....	50 mgrms.
Silver       " .....	90. "

Then we have :

Free gold  $\frac{1.9}{100}$  oz. per ton of original ore.

Silver in free gold  $\frac{2.5}{100}$  oz. per ton of original ore.

Gold in sulphurets  $\frac{6.4}{100}$  oz. per ton of original ore.

Silver in sulphurets  $\frac{1.6}{100}$  oz. per ton of original ore.

Total gold  $\frac{8.3}{100}$  oz. per ton of original ore.

Total silver  $\frac{4.1}{100}$  oz. per ton of original ore.

There is a certain loss in panning, hence the results are not analytically accurate, but are close indications of the practical result of the working of gold ores in a mill with copper plates.\*

## VI. CHLORINATION ASSAY OF GOLD ORES.

If gold exists free in the gangue, that is, not combined with sulphur, arsenic or tellurium, it can be chlorinated directly without roasting.

\* For the information comprised in the above article I am largely indebted to Mr. S. A. Reed of Irwin, Col., and Mr. Ray G. Coates of Chicago,



But sulphurets, arseniurets or tellurides must be first roasted and thoroughly at that.

The chlorination can be done in the laboratory on either a large or moderately large scale. For the former, operating say on 20 pounds ( $\frac{1}{100}$  of a ton), consult the section in Kustel, entitled "Extraction of Gold from Sulphurets, Arseniurets or Quartz, by Chlorination," pp. 136-139.

For the latter grind up 5 to 8 ounces (or 5 to 10 A. T.), and, if necessary, roast in the usual manner. Use a frying pan for this purpose, and see that the sulphur is entirely driven out so that no smell (as of a burning match) is perceptible at the finish. Cool, grind in an iron mortar, and re-roast at a red heat.

When cold, reserve 1 A. T. of the ore for regular assay; the remainder is to be chlorinated in the apparatus herewith described. It consists of a flask, provided with a funnel tube for acid supply and delivery tube for the chlorine gas generated. The latter tube dips into

a wash bottle containing water to wash the gas. From the latter the gas passes up into a separatory funnel containing the ore. The exit tube from the funnel may pass into a flue or the open air, or into a cylinder holding shavings moistened with alcohol.

Place in the flask a mixture of 3 parts of black oxide of manganese, 4 parts of common salt, and  $4\frac{1}{2}$  parts of water, all well mixed.

Place the ore, which has been dampened with water, in the separatory funnel, having put in at the bottom a very little cotton to prevent the fine ore from stopping the passage of the gas.

Having now made all ready, pour down through the funnel tube  $7\frac{1}{2}$  parts of sulphuric acid at intervals. After a time the flask is to be gently heated, that all the chlorine may be driven off.

Run the operation for about two hours, then disconnect the flask and let the funnel stand over night. Finally take out the upper

cork and wash out the chloride of gold with distilled water.

To the solution in a beaker or tumbler add a few drops of hydrochloric (muriatic) acid, then some solution in water of sulphate of iron (green vitriol or copperas), stir with a glass rod, warm and let stand undisturbed until all the gold has been thrown down to the bottom and the liquid above is perfectly clear. Half of this liquid is drawn off with a syphon, the remainder containing the gold is filtered as usual, washing with warm water. Dry the filter, burn, scorify ashes and cupel, or cupel directly with sheet lead, weigh, etc. Compare result with unchlorinated sample. Consult Kustel as above, and Ricketts, p. 194.

#### VII. CHLORINATION TEST FOR SILVER.

In smelting-works it is often necessary to test ores that have been subjected to chloridizing roasting, to ascertain the amounts of chloride of silver contained in them. Two assays are made of each ore.

Several pounds of the ore are taken from various portions of the entire lot, well mixed and sifted. From this, weigh out two charges of  $\frac{1}{10}$  A. T. Scorify and cupel one charge in the usual manner.

The other charge is brushed into a filter paper held in a glass funnel, and over it pour a *warm* solution of hyposulphite of soda (six or eight ounces in a quart of water), which rapidly dissolves the chloride of silver from the ore. Continue this treatment until a small portion of the filtered liquid contained in a test-tube, darkens but slightly and does not lose its transparency upon the addition of a few drops of a solution in water of sulphide of sodium.

Wash the mass in the filter with warm water, remove filter and all, dry and burn in scorifier in muffle, at a low heat, mix ashes with lead, scorify and cupel as usual.

(The hyposulphite solution dissolves out sulphate of silver as well as the chloride. If, as is sometimes the case, it is desired to know

the amount of sulphate present, leach a third charge with warm water, which will take out the sulphate, but will not touch the chloride or any unacted-upon ore. Scorify and cupel the residue as directed.)

The difference between the two cupellations shows the amount of silver which has been changed into the state of a chloride. Thus :

1st charge ran 180 oz. per ton.

2d charge ran 10 oz. per ton.

Hence,  $180 - 10 = 170$  oz. of chloridized pulp.

To obtain percentage :

$180 : 170 :: 100 : x = 94.4$  per cent.

“If there should be gold in the ore, this must be subtracted from both assays, because, although the amount of gold would be equal, the chlorination result, as it should be, must come out higher after the gold is subtracted.” (Kustel.)

#### VIII. THE ASSAY OF GOLD BULLION.

(Consult “Report upon the Wastage of Silver Bullion in the Melter and Refiner’s De-

partment of the Mint of the United States, July 25, 1872, pp. 60-65, 'The Assay of Gold.' " I am also indebted to Mr. C. Boyer, Assayer of the Branch Mint at Denver, Colo., for valuable information herein embodied.)

Secure sample for assay by cutting off a corner of the ingot or bar, which is supposed to be of uniform character.

Flatten sample on anvil and pass through rolls once or twice, or till the slip is thin enough to be easily cut by shears.

A special set of weights known as "gold weights" is used in the U. S. Mint and branches. The unit of the system is a "1000" piece; from that the weights range down to a  $\frac{1}{10000}$  piece. The gold and silver are reported in thousandths, that is, in parts of a thousand, hence the use of such weights. The actual weight of each piece in the set of "gold weights" is one-half of its corresponding piece in the French or Metric system, thus the "1000" weight weighs actually 500 mgrms., and so on.

Weigh out very carefully "1000" of the sample (or 500 mgrms.), and add *twice* as much pure silver (foil) as there is gold, allowing for the silver assumed to be in the sample. (The fineness of the sample is determined by comparison with slips of known fineness; in time the assayer can determine this without such aid.) For example a sample is thought to be 900 fine, that is, made up of 900 parts gold and 100 parts silver; total, 1000. Add then 1700 parts silver, which with the 100 parts already in the sample will make 1800 or twice the 900 parts of gold.

If the slip appears to contain very little copper add a small piece, say 50 mgrms. Wrap the gold, silver and copper in a piece of pure lead foil of about ten times the weight of the assay; squeeze all into a bullet.

Cupel in the usual manner. When all the lead has been cupelled away, remove from muffle, detach button, flatten on anvil, and anneal by heating on an annealing plate in the muffle. Take out, pass through the rolls,

anneal again and form into a coil known as a cornet.

Introduce into a parting flask or matrass, one ounce of pure nitric acid of 32° Beaumé (specific gravity 1.26, see page 162), add a pinch of *thoroughly charred* wood charcoal (see Mitchell, page 165), and heat to boiling on sand bath. Now place the cornet in the matrass, and boil for ten minutes. Pour off, add a second charge of  $\frac{3}{4}$  of an ounce of same strength acid, and boil for ten minutes again.

Pour off the acid and wash the cornet thoroughly with distilled water. Add a couple of ounces of water to the matrass, place an annealing cup over the top and invert; by this means the cornet is deposited without loss or injury in the cup. Decant out of this the water and heat the cup containing the cornet, at first gently on the sand bath till all the moisture has been driven off, then in the muffle, making the third time of annealing.

Weigh the cornet, using the gold weights (or the gramme weights and multiplying by



two). The result will be the amount of gold in the bullion or the fineness.

By subjecting another "1000" of the sample to cupellation *without* silver, the base metal is oxidized off, leaving the gold and silver on the cupel. "The loss gives the proportion of base metal and the difference between the "1000" (the original weight) and the sum of the fineness of the gold and the amount of base metal will be the amount of silver in the alloy."

#### IX. THE ASSAY OF BASE BULLION.

The uncertainty in the assay of base bullion lies, not in the determination of the amounts of gold and silver present, but in the difficulty of obtaining an average sample.

This question has given rise to an amicable discussion in the columns of the Engineering and Mining Journal, between various parties interested (issues of May 20, June 3, July 1, and Sept. 9, 1882), eliciting some valuable information which I purpose to reproduce herewith.

A base bullion may contain lead, silver, gold, copper, arsenic, antimony, and perhaps other metals, and sulphur. When this is melted and cooled, it tends to form alloys of varying degrees of fusibility, which with the dross or scum (a mixture of oxides, sulphides, etc.) make a pig or bar from which it is not an easy matter to select a fair sample for assay.

In many smelting establishments the surface of the melted bullion is skimmed, and the clear lead ladled into the mould, till the latter is filled to within an inch of the top, and when it has solidified, the mould is filled completely. There results then a nice-looking bar, composed of good lead above and below, with much dross in the centre. This would not matter so much if an equal portion of the dross could be gotten at, for assay, but there's the rub. The ordinary way of chipping the top and bottom of the bar does no good, since it seldom cuts deeper than  $\frac{1}{8}$  inch below the surface. Even a punch cutting a

chip  $\frac{3}{4}$  inch deep does not solve the problem, for it will not reach the dross when cast in the middle of the bar.

Mr. L. S. Austin in the issue of Sept. 9 of the journal quoted suggests a method which seems to meet the requirement. "It consists in the use of the punch which I have already described, [June 3d issue] and which takes a chip of about  $\frac{1}{8}$  inch in diameter and uniform in thickness. It is driven clear in to one-half the depth of the bar by the use of a sledge. The bar being, say four inches in depth, a chip a little over two inches long is then taken both from top and bottom of the bar. The chip is then slipped into a hole bored two inches deep into a block, and the projecting lower end trimmed off with shears to the exact length of two inches. Each chip represents consequently one-half the bar, its companion representing the other half; moreover, each chip is of the same weight. Thus each bar is represented according to its relative weight and to its entire depth."

Having obtained these chips, they are next melted, and poured into a small mould. Take this sample bar, cut slices across, each slice being a section of the bar. Cut from these slices  $\frac{1}{2}$  A. T. for assay. By running five of these  $\frac{1}{2}$  A. T. assays, and uniting the silver beads obtained, for parting, the gold present can be accurately determined.

Cupel the samples, "feathering" the cupels. Brittle or hard bullion can be scori-fied first, if necessary.

Consult the numbers of the journal referred to.

#### X. COLOR TESTS.

*Scorification.*—During the first part of the process of scorification of ores that have not been roasted or only partially so, the colors of the fumes given off will often indicate the nature of the ore.

Thus sulphur emits clear gray vapors ; zinc, blackish vapors, and a brilliant white flame ; arsenic, whitish-gray vapors ; and antimony, fine red vapors (Mitchell).

*Scorifiers*.—The colors shown by the interiors of scorifiers after scorification are often characteristic.

*Lead* tends to color the scorifier a lemon-yellow.

*Iron* colors it in various shades of reddish-brown, from a brick-red to a deep rich mahogany.

*Copper*, according to its percentage, gives a green, ranging from light to very dark.

*Tellurium* colors the scorifier a deep blood-red.

Combinations of the metals are liable to influence these colors, and produce mixed shades.

*Cupels*.—The color and appearance of a cupel are occasionally indices of the metals present in the ore.

Antimony: Litharge-yellow to brownish-red scorix, cupel often cracks (Mitchell).

Arsenic: White or pale yellow scorix (Triplet).

Bismuth: An orange-yellow color (North).

Chromium: Dark brick-red stain (Triplett).

Cobalt: Dark green scoriæ; greenish stain (Triplett).

Copper: Dark purplish-black stain, sometimes with a greenish cast or even a brown, at times a gray or dirty red; the edges show a purplish-red tint; there is generally a *rose* coat on the outside of cupels from ores rich in copper, which need not be mistaken for the rose color of oxide of silver.

Iron: From light through dark brown to almost black; corroded rings on cupel.

Lead: Lemon-yellow, straw or orange-yellow.

Manganese: Dark bluish-black stain; cupel corroded (Triplett).

Palladium and Platinum: Greenish stains and crystalline buttons (Triplett).

Tin: Gray scoriæ.

Zinc: Yellowish ring on cupel, often causes loss of silver by ebullition; flame very luminous.

## XI. QUALITATIVE TESTS.

I have thought it a good plan to give a few simple wet tests for some of the metals, and acids united with them, as found in ores.

Ordinarily these tests work better on the powdered ore, though sometimes, as will be mentioned, the original rock can be directly treated.

*Carbonates.*—Place a drop of any strong acid upon the suspected rock ; if effervescence (or boiling up) ensues, unaccompanied by any odor, it contains carbonates. This test does not always show well with small quantities of carbonates ; try then some of the powdered ore with acid in a test-tube. To confirm the presence of carbonic acid, suspend in the test-tube a glass rod that has previously been dipped in lime-water ; the drop on the rod should become turbid or milky, owing to the formation of carbonate of lime.

Place a small sample of the pulverized ore in a test-tube, add to it some nitric acid, a little more than will cover it, and heat till the

acid does not seem to dissolve any more of the ore; let cool, after which add as much *pure water* as there is acid, and shake.

Filter, in manner described under "Copper Analysis," p. 212.

*Sulphates*.—To some of the filtered acid solution add solution of chloride of barium (or, if lead be present, of nitrate of barium). A white cloudiness or precipitate (which does not instantly form in dilute solutions) shows the presence of sulphates.

*Sulphides*.—To a piece of the rock, or to some of the powdered ore, add a drop of nitric acid. If sulphides are present in any quantity, a strong odor, similar to that of rotten eggs, will be given off.

*Tellurides*.—Take a small piece of the ore and place it on the cover of a porcelain capsule, and heat with the inner flame of the blow-pipe for a couple of minutes. Now place a drop of *concentrated* sulphuric acid on the cover, and let it slide down to the heated fragment. As soon as it touches or ap-



proaches very near the ore a beautiful carmine coloration forms, strongly contrasting with the white porcelain. As the latter cools, the color fades. Any white crockery, as a piece of a broken plate or saucer, will do to use in this test.

*Copper.*—To a piece of the rock on a white porcelain surface add a few drops of nitric acid and stir. Add now an excess of ammonia water. If the mass turns blue, copper or its compounds is undoubtedly in the ore. If the latter contains much copper, a polished knife-blade dipped in an acid solution of it will receive a coating of metallic copper.

*Iron.*—If, at the same time the solution treated with ammonia turns blue, or even if it does not do so, there appears on the porcelain or in the test-tube, a reddish-brown gelatinous mass, then iron is present.

As further tests for iron, on one part of an old plate put a crystal of sulphocyanide of potassium and on another a lump of ferrocyanide of potassium (yellow prussiate of potash);

now pour on each a little of a hydrochloric acid solution of an ore containing iron ; a blood-red coloration with the first-named re-agent, and a magnificent blue precipitate with the second, prove conclusively the presence of iron compounds. Of course these tests can be shown with the filtered solution in test-tubes.

*Lead.*—Drop a little nitric acid upon a piece of ore supposed to contain lead, then add a little water, and finally a crystal of iodide of potassium. A bright-yellow precipitate will form if lead is present.

*Silver.*—If this metal is in any appreciable quantity in an ore, it will dissolve in nitric acid (excepting the chloride ores). To the acid solution, add a little hydrochloric acid, solution of common salt, or even a dry grain or two of the latter. A curdy, white precipitate of chloride of silver is thrown down, which is not soluble in water (as is chloride of lead on the contrary), but dissolves easily in ammonia water. The precipitate turns black on being exposed to light.

As stated above, chloride ores do not dissolve in nitric acid; therefore when they are suspected to be present, put some of the powdered ore into a small bottle, pour in a small quantity of very strong ammonia water, cork up the bottle and let it stand for a few hours. Then add, in slight excess, nitric acid. The white precipitate of silver chloride will at once come down if there is any in the ore.

The best test for gold is the fire assay. To learn the colors and appearances of the tests above given, try them on the following substances:

Carbonates .....	Bi-carbonate of Soda.
Chlorides .....	Common Salt.
Sulphates .....	Sulphuric Acid.
Sulphides.....	Copper or Iron Pyrites.
Tellurides .....	Any Telluride Ore.
Copper .....	Copper Wire.
Iron .....	Nail or Wire.
Lead.....	Sheet Lead or Galena.
Silver .....	Silver Foil and Horn Silver.

Consult the books on qualitative analysis for further information or tests.

## XII. BRIEF SCHEME FOR SILICA, IRON AND MANGANESE.

It is very often the case that the percentages in an ore of the above mentioned substances are wanted. More particularly is this true with carbonate ores. Hence the following notes:

Dissolve the weighed ore in hydrochloric acid by the aid of heat. Filter hot and wash with hot water. The filtrate contains the iron, with chloride of lead, etc.

The silica on filter contains chloride of lead. Wash this out with hot solution of citrate of ammonium, following with hot water. Ignite the silica while still damp.

To the iron in solution in the filtrate, add sufficient sulphuric acid to convert all the lead into sulphate of lead. Warm the solution if not already so, and add, drop by drop, dilute stannous chloride solution, until the liquid becomes colorless, showing that the iron is all reduced to state of protoxide. Avoid a great excess of the tin solution. Now cool,

and add, *all at once*, an excess of strong mercuric chloride solution. The precipitate formed should be perfectly white. If dark colored, it indicates that insufficient mercuric chloride has been used, and the analysis is spoiled. If the precipitate is all right, the solution is ready for titration with standard bi-chromate of potash solution. (Consult Fresenius' "Qualitative and Quantitative Analysis," and Hart and Sutton on "Volumetric Analysis.")

For manganese in ores (excepting silicates), heat a weighed sample in crucible in open fire for fifteen minutes, converting the manganese into protosessquioxide of manganese. Treat with hydrochloric acid, and titrate with iodide of potassium and hyposulphite of sodium. (See Sutton.)

### XIII. DETERMINATION OF MOISTURE IN AN ORE.

It is often a matter of importance to know the amount of moisture or water contained in an ore. The simplest manner in which to

determine this, and a satisfactory one at that, is to sample out a certain weight, say *five grammes*, and transfer to a porcelain capsule, the weight of which is already known. Expose the capsule and contents to steam-heat in any convenient way, for one-half hour, then weigh. Heat half an hour longer and weigh again. There should be but a slight difference in the last two weighings. The difference between the last weight and the original weight of dish and ore, is the loss by driving off the water; this difference divided by the amount of ore taken, and multiplied by 100, is the percentage of moisture in the ore.

## SECTION II.

### LISTS AND REFERENCES.

#### GOLD.

#### LIST OF THE PRINCIPAL GOLD MINERALS FOUND IN THE UNITED STATES.

NAME.	COMPOSITION.
1. Calaverite (telluride of gold).	Gold, tellurium.
2. Gold amalgam.	Gold, mercury.
3. Electrum (argentiferous gold).	Gold, silver.
• 4. Müllerite (telluride of gold, silver and lead).	Gold, silver, lead, tellurium.
5. Nagyagite (black tellurium, foliated tellurium, telluride of gold and lead).	Gold, lead, tellurium (antimony, sulphur).
6. Native gold (flour, leaf, wire, nugget, free, etc.).	Gold.
7. Petzite (telluride of gold and silver).	Gold, silver, tellurium.
8. Sylvanite (graphic tellurium, yellow tellurium, telluride of gold and silver)	Gold, silver, tellurium (antimony).

## MINERALS LIKELY TO CARRY GOLD.

- |                    |                     |
|--------------------|---------------------|
| 1. Aikinite.       | 14. Magnolite.      |
| 2. Altaite.        | 15. Melaconite.     |
| 3. Argentite.      | 16. Native arsenic. |
| 4. Arsenopyrite.   | 17. " bismuth.      |
| 5. Bismuthinite.   | 18. " silver.       |
| 6. Chalcopyrite.   | 19. " tellurium.    |
| 7. Coloradoite.    | 20. Pyrite.         |
| 8. Ferro-tellurite | 21. Sphalerite.     |
| 9. Galenite.       | 22. Tellurite.      |
| 10. Henryite.      | 23. Tellurpyrite.   |
| 11. Hessite.       | 24. Tetradymite.    |
| 12. Joseite.       | 25. Tetrahedrite.   |
| 13. Lionite.       | 26. Wehrlite.       |

## SILVER.

LIST OF THE PRINCIPAL SILVER MINERALS FOUND IN  
THE UNITED STATES.

- | NAME.   | COMPOSITION.                            |
|---|---|
| 1. Alaskaite (sulphide of bismuth, silver and lead).                            | Silver, bismuth, lead, copper, sulphur. |
| 2. Argentite (sulphuret or sulphide of silver, vitreous silver, silver glance). | Silver, sulphur.                        |
| 3. Bromyrite (bromide of silver, bromic silver).                                | Silver, bromine.                        |



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| 4. Cerargyrite (muriate or chloride of silver, horn-silver)              | Silver, chlorine.                           |
| 5. Dyscrasite (antimonial silver).                                       | Silver, antimony.                           |
| 6. Electrum (argentiferous gold).  | Silver, gold.                               |
| 7. Embolite (chloro-bromide of silver).                                  | Silver, chlorine, bromine.                  |
| 8. Freieslebenite (antimonial sulphide of silver and lead).              | Silver, lead, antimony, sulphur.            |
| 9. Hessite (telluride of silver, telluric silver).                       | Silver, tellurium.                          |
| 10. Iodyrite (iodide of silver, iodic silver).                           | Silver, iodine.                             |
| 11. Miargyrite (sulphide or sulphuret of silver and antimony)            | Silver, antimony, sulphur.                  |
| 12. Native silver (free, wire, leaf, dendritic, etc.).                   | Silver.                                     |
| 13. Petzite (telluride of silver and gold).                              | Silver, gold, tellurium.                    |
| 14. Polybasite (sulphide of silver, antimony and arsenic).               | Silver, antimony, arsenic, copper, sulphur. |
| 15. Proustite (arsenical silver ore, light red silver ore, ruby silver). | Silver, arsenic, sulphur.                   |

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| 16. Pyrargyrite (antimonial red silver ore, dark red silver ore, ruby silver).       | Silver, antimony, sulphur.  |
| 17. Schapbachite (bismuth-silver, sulphide of bismuth, silver and lead).             | Silver, bismuth, lead, sulphur.   |
| 18. Schirmerite (same as above but proportions varying).                             | Silver, bismuth, lead, sulphur.   |
| 19. Stephanite (sulphide of silver and antimony, brittle silver, black silver).      | Silver, antimony, sulphur.  |
| 20. Sternbergite (sulphide of silver and iron).                                      | Silver, iron, sulphur.  |
| 21. Stetefeldite (oxide of antimony with silver, etc.).                              | Silver, antimony, copper, oxygen, sulphur.                                |
| 22. Stromeyerite (sulphide or sulphuret of silver and copper, silver-copper glance). | Silver, copper, sulphur.  |
| 23. Sylvanite (graphic tellurium, yellow tellurium, telluride of silver and gold).   | Silver, gold, tellurium (antimony).                                       |
| 24. Tetrahedrite (gray copper ore, sulphide of copper, antimony, silver, etc.).      | Silver, copper, antimony, sulphur (arsenic, bismuth, mercury, zinc, etc.) |

## MINERALS LIKELY TO CARRY SILVER.

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|----------------------|----------------------|
| 1. Algodonite.       | 22. Melaconite.      |
| 2. Altaite.          | 23. Müllerite.       |
| 3. Arsenopyrite.     | 24. Nagyagite.       |
| 4. Barnhardite.      | 25. Native antimony. |
| 5. Bornite.          | 26. " arsenic.       |
| 6. Boulangerite.     | 27. " bismuth.       |
| 7. Calaverite.       | 28. " copper.        |
| 8. Cerussite.        | 29. " gold.          |
| 9. Chalcopyrite.     | 30. " mercury.       |
| 10. Coloradoite.     | 31. " tellurium.     |
| 11. Enargite.        | 32. Petzite.         |
| 12. Ferro-tellurite. | 33. Pyrite.          |
| 13. Galenite.        | 34. Realgar.         |
| 14. Geocronite.      | 35. Smaltite.        |
| 15. Gold amalgam.    | 36. Sphalerite.      |
| 16. Henryite.        | 37. Sylvanite.       |
| 17. Hessite.         | 38. Tellurite.       |
| 18. Joseite.         | 39. Tellurpyrite.    |
| 19. Leucopyrites.    | 40. Tétradymite.     |
| 20. Lionite.         | 41. Wehrlite.        |
| 21. Magnolite.       |                      |

## COPPER.

LIST OF THE PRINCIPAL COPPER MINERALS FOUND IN  
THE UNITED STATES.

NAME.	COMPOSITION.
1. Aikinite (needle ore, acicular bismuth, cupreous bismuth).	Copper, bismuth, lead, sulphur.
2. Algodonite (arsenide of copper).	Copper, arsenic.
3. Atacamite (muriate of copper, oxy-chloride of copper).	Copper, chlorine, oxygen (water).
4. Aurichalcite (carbonate of zinc and copper).	Copper, zinc, carbon, oxygen (water).
5. Azurite (mountain blue, blue carbonate of copper, blue malachite, azure copper ore).	Copper, carbon, oxygen (water).
6. Barnhardite (sulphide of iron and copper).	Copper, iron, sulphur.
7. Bornite (purple copper ore, variegated copper ore, <i>erubescite</i> , sulphide of copper and iron).	Copper, iron, sulphur.
8. Bournonite (triple sulphuret of copper, lead and antimony).	Copper, lead, antimony, sulphur.
9. Brochantite (sulphate of copper).	Copper, oxygen, sulphur (water).

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| 10. Caledonite (cupreous sulphato-carbonate of lead).                             | Copper, lead, carbon, oxygen, sulphur. |
| 11. Carrollite (sulphide of cobalt (nickel) and copper).                          | Copper, cobalt (nickel), sulphur.      |
| 12. Chalcanthite (blue vitriol, copper vitriol, sulphate of copper).              | Copper, oxygen, sulphur (water).       |
| 13. Chalcocite (copper glance, vitreous copper, sulphuret or sulphide of copper). | Copper, sulphur.                       |
| 14. Chalcopyrite (copper pyrites, pyritous copper, sulphide of copper and iron).  | Copper, iron, sulphur.                 |
| 15. Chrysocolla (mountain green, mountain blue, silicate of copper).              | Copper, silicon, oxygen (water).       |
| 16. Covellite (indigo copper, blue copper, sulphide of copper).                   | Copper, sulphur.                       |
| 17. Cuprite (red oxide of copper, cupreous oxide).                                | Copper, oxygen.                        |
| 18. Domeykite (arsenical copper, arsenide of copper).                             | Copper, arsenic.                       |
| 19. Enargite (sulph-arsenite of copper).  | Copper, arsenic, sulphur.              |
| 20. Harrisite (sulphide of copper)  | Copper, sulphur.                       |

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| 21. Malachite (mountain green, green carbonate of copper, green malachite, green copper).         | Copper, carbon, oxygen (water).  |
| 22. Melaconite (black oxide of copper, black copper, cupric oxide).                               | Copper, oxygen.  |
| 23. Native copper (sometimes with silver).  | Copper (silver).   |
| 24. Pseudomalachite (phosphate of copper).  | Copper, oxygen, phosphorus (water).                                      |
| 25. Stromeayerite (sulphuret of silver and copper, silver-copper glance).                         | Copper, silver, sulphur.   |
| 26. Tennantite (sulph-arsenite of copper).  | Copper, arsenic, sulphur (iron).   |
| 27. Tetrahedrite (gray copper ore, sulphide of copper and antimony with various other sulphides). | Copper, antimony, sulphur (arsenic, bismuth, silver, mercury, zinc, etc) |
| 28. Torbernite (copper-uranite, phosphate of uranium and copper).                                 | Copper, uranium, phosphorus, oxygen (water).                             |
| 29. Uranochalcite (oxide of uranium with oxide of copper and sulphate of lime)                    | Copper, uranium, oxygen, sulphur, calcium (water).                       |

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|---|---------------------------------|
| 30. Vanquelinite (chromate of copper and lead). | Copper, lead, chromium, oxygen. |
| 31. Whitneyite (arsenide of copper).            | Copper, arsenic.                |

## LEAD.

## LIST OF THE PRINCIPAL LEAD MINERALS FOUND IN THE UNITED STATES.

NAME.	COMPOSITION.
1. Alaskaite (sulphide of bismuth, silver and lead).	Lead, bismuth, silver, copper, sulphur.
2. Altaite (telluride of lead).	Lead, tellurium.
3. Anglesite (lead-vitriol, sulphate of lead).	Lead, oxygen, sulphur.
4. Boulangerite (sulphide of lead and antimony).	Lead, antimony, sulphur.
5. Bournonite (triple sulphuret of copper, lead and antimony).	Lead, copper, antimony, sulphur.
6. Caledonite (cupreous-sulphato-carbonate of lead).	Lead, carbon, copper, oxygen, sulphur.
7. Cerussite (white lead ore, carbonate of lead).	Lead, carbon, oxygen.
8. Dechenite (vanadate of lead and zinc).	Lead, vanadium, zinc, oxygen.
9. Descloizite (vanadate of lead).	Lead, vanadium, oxygen.

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| 10. Freieslebenite (antimonial sulphide of silver and lead). | Lead, silver, antimony, sulphur.              |
| 11. Galenite (galena, sulphide or sulphuret of lead).        | Lead, sulphur.                                |
| 12. Geocronite (sulph-arseno-antimonite of lead).            | Lead, antimony, arsenic, sulphur.             |
| 13. Henryite (telluride of lead, with a little iron).        | Lead, tellurium, iron.                        |
| 14. Jamesonite (sulph-antimonite of lead).                   | Lead, antimony, sulphur (iron).               |
| 15. Kobellite (sulphide of lead, bismuth and antimony).      | Lead, bismuth, antimony, sulphur.             |
| 16. Lanarkite (sulphato-carbonate of lead).                  | Lead, carbon, oxygen, sulphur.                |
| 17. Leadhillite (sulphato-tri-carbonate of lead).            | Lead, carbon, oxygen, sulphur.                |
| 18. Massicot (plumbic ochre, yellow oxide of lead).          | Lead, 1 part; oxygen, 1 part.                 |
| 19. Mimetite (green lead ore, arsenate of lead).             | Lead, arsenic, oxygen (chlorine, phosphorus). |
| 20. Minium (red oxide of lead).                              | Lead, 3 parts; oxygen, 4 parts.               |
| 21. Müllerite (telluride of gold, silver and lead).          | Lead, gold, silver, tellurium.                |



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| 22. Nagyagite (black tellurium, foliated tellurium, telluride of gold and lead). | Lead, gold, tellurium (antimony, sulphur). |
| 23. Native lead.   | Lead.                                      |
| 24. Plumbogummite (phosphate of alumina and lead).                               | Lead, aluminum, oxygen, phosphorus.        |
| 25. Pyromorphite (phosphate and chloride of lead).                               | Lead, phosphorus, oxygen, chlorine.        |
| 26. Schapbachite (bismuth-silver, sulphide of bismuth, silver and lead).         | Lead, bismuth, silver, sulphur.            |
| 27. Schirmerite (same as above but proportions varying).                         | Lead, bismuth, silver, sulphur.            |
| 28. Stolzite (tungstate of lead).  | Lead, tungsten, oxygen.                    |
| 29. Vanquelinite (chromate of copper and lead).                                  | Lead, copper, chromium, oxygen.            |
| 30. Wulfenite (yellow lead ore, yellow lead-spar, molybdate of lead).            | Lead, molybdenum, oxygen.                  |

*Note.*—For descriptions of the above, and of other American and foreign minerals of gold, silver, copper and lead, consult Dana's System of Mineralogy, 5th Ed. with Sup., and Prof. J. Alden Smith's Report as State Geologist of Colorado, for 1880.

LIST OF USEFUL BOOKS ON SUBJECTS MORE OR LESS  
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*Fresenius, C. R.*: Manual of Quantitative Chemical Analysis. 7th English edition. London, 1876.

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*Morfit (Campbell and Clarence)*: Chemical and Pharmaceutical Manipulations. Phila., 1857.

*Williams, C. G.*: A Hand-book of Chemical Manipulation. London, 1857; supplement, 1879.

*Geology.*

*Cotta, Bernh. v.* Treatise on Ore Deposits. Translated from 2d German edition by F. Prime, and revised by author. New York, 1870.

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*Dana, J. D.*: Manual of Geology. New York, 1881.

*Le Conte, Joseph*: Elements of Geology. A text-book for colleges and for the general reader. New York, 1878.

*Rutley, C. L.*: The Study of Rocks. 2d edition. New York, 1880.

*Mineralogy.*

*Dana, J. D.*: A System of Mineralogy. 5th edition, 1868; Appendix I, 1872; Appendix II, 1875; Appendix III, 1882. New York.

*Dana, J. D.:* Manual of Mineralogy and Lithology.  
3d edition. New York, 1878.

*Brush, G. J.:* Manual of Determinative Mineralogy,  
with an Introduction on "Blow-pipe Analysis."  
New York, 1878.

*Foye, J. C.:* Tables for the Determination, Description  
and Classification of Minerals. Chicago, 1882.

*Frazer, P.:* Tables for the Determination of Minerals.  
Phila., 1874.

*Blow-Pipe Analysis.*

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ysis with the Blow-pipe. Translated by H. B.  
Cornwall. 2d edition. New York, 1873.

*Cornwall, H. B.:* Manual of Blow-pipe Analysis, Qual-  
itative and Quantitative. With a Complete Sys-  
tem of Determinative Mineralogy. New York,  
1882.

*Attwood, Geo.:* Practical Blow-pipe Assaying. New  
York, 1881.

*Plympton, G. W.:* The Blow-pipe. A Guide to its Use  
in the Determination of Salts and Minerals. New  
York, 1874.

*Elderhorst, Wm.:* Manual of Qualitative Blow-pipe  
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*Metallurgy and Mining.*

*Kerl, Prof.:* Practical Treatise on Metallurgy. Trans-

lated by Wm. Crookes and E. Röhrig. Vol. 1, Lead, Silver, Zinc, etc., 1868; Vol. 2, Copper and Iron, 1869; Vol. 3, Steel, Fuel and Supplement, 1870. London.

*Lock, A. G.*: Gold; Its Occurrence and Extraction. London and New York, 1882.

*Percy, John*: Metallurgy. The Art of Extracting Metals from their Ores. Part I, Silver and Gold. London, 1880.

*Percy, John*: The Metallurgy of Lead. London, 1870.

*Percy, John*: The Metallurgy of Fuel, Wood, Peat, Coal, Charcoal, Fire-clays. Revised edition.

*Callon, J.*: Lectures on Mining. 3 vols. London and Paris, 1876-81.

*Lamborn, R. H.*: Metallurgy of Copper. 6th edition. London, 1875.

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*Kustel, G.*: Roasting of Gold and Silver Ores, and the Extraction of their Respective Metals without Quicksilver. New edition (2d). San Francisco, 1880.

*Makin, G. H.*: A Manual of Metallurgy. 2d edition. London, 1873.

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- Balling, C. A. M.*: Die Probirkunde des Eisens und der Brennmaterialen. Prag, 1868.
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- Bodeman, Th.*, and *Bruno Kerl*: Anleitung zur Berg-und Hüttenmännischen Probirkunde. 2d edition. Clausthal, 1857.
- Bodemann, Th.*, and *Bruno Kerl*: A Treatise on the Assaying of Lead, Copper, Silver, Gold and Mercury. Translated by W. A. Goodyear. New York, 1865.
- Kerl, Bruno*: Metallurgische Probirkunst. 2d edition. Leipsig, 1882.
- Lieber, O. M.*: The Assayer's Guide. Phila., 1852.
- Mitchell, John*: A Manual of Practical Assaying. Edited by Wm. Crooks. 5th edition. New York, 1881.
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- Overman, F.*: Practical Mineralogy, Assaying and Mining. Phila., 1851.
- Phillips, J. S.*: The Explorers' and Assayers' Companion. San Francisco, 1879.
- Ricketts, P. de P.*: Notes on Assaying and Assaying Schemes. New York, 1879.

*Silversmith, J.*: A Practical Hand-book for Miners, Metallurgists and Assayers. New York, 1866.

*Triplett, Frank*: How to Assay. St. Louis, 1881.\*

*Metric System; Weights and Measures.*

*Barnard, F. A. P.*: The Metric System of Weights and Measures. 2d edition. New York, 1872.

*Eggleston, T.*: Tables of Weights, Measures, Coins, etc. New York, 1871.

*Mining Law.*

*Copp, H. N.*: American Mining Code. 3d edition. 1880.

*Carpenter, M. B.*: Mining Code. 3d edition. 1880.

*Wade, W. P.*: Manual of Mining Law. St. Louis. 1882.

*Wilson, C. S.*: Mining Laws of the United States, Colorado, New Mexico and Arizona. 1881.

It is not pretended that the above list is complete, nor even that it comprises all the best works; it is simply a list of some that are considered standard authorities in their respective lines, save perhaps in the department of assaying, where certain ones are included that are not particularly valuable.

\* Besides the above, there have been a number of publications from 1741 to about 1850 which are either obsolete in their teachings, or the information contained therein is embraced in the preceding.



Almost every assayer has his own particular blank, but so long as the certificate states plainly the results of his work, any little differences of detail are unimportant. The form given below is about as satisfactory as any.

No.	Description.	Gold, No. of ounces per ton.	Value at \$----- per oz.	Silver, No. of ounces per ton.	Value at \$----- per. oz.	Total Value of Gold and Silver.	Cop- per, per cent.	Lead, per cent.	Remarks.

Assayer.

## OUTFIT.

With the following outfit, it is believed the assayer can perform the ordinary crucible and scorification assays of gold, silver, copper and lead ores :

Hammers, sledge, medium and small .....	\$2 00
Iron mortar (8 inch diam., 1 gal. capacity) and pestle, wt. 19 lbs.....	1 25
Steel spatulas, one large and one small .....	75
Sieves, 20, 40 and 100 mesh.....	2 50
Hand-scales for fluxes.....	3 00
Ore or pulp scales .....	22 00
Assay balance, with weights (1 grm down to $\frac{1}{10}$ mgrm) .....	65 00
Set gramme weights, 100 grms down .....	6 00
Set assay ton weights .....	6 50
Furnace, Brown's portable.....	20 00
6 Muffles, Battersea J.....	8 25
1 pair crucible tongs .....	1 25
1 pair scorifier tongs .....	1 00
1 pair cupel tongs .....	1 00
Shovel, scraper and hoe .....	75
Scorification mould .....	1 00
Crucibles, S. T. U. V., 1 doz each, with covers	4 50
Crucibles, Colorado, 2 doz.....	1 10

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Scorifiers, 200 $2\frac{3}{4}$ inch, 200 $2\frac{1}{4}$ inch.....	9 50
Cupels, 4 doz. 1 inch .....	3 00
Cupel mould .....	2 25
Piece rubber cloth .....	1 00
Alcohol lamp.....	50
Ring stand.....	1 00
Wire triangle.....	10
1 doz. 1 inch porcelain capsules .....	2 00
1 doz. $1\frac{1}{4}$ inch porcelain capsules .....	2 50
1 quart wash-bottle .....	75
1 pair 3 inch watch-glasses .....	50
Blow-pipe.....	20
Magnifying glass, pocket size .....	75
Magnet ....	20
Small steel hammer and anvil.....	1 75
Pair brass pincers.....	25
Small cold chisel .....	50
Horn spoon .....	25
1 lb. bottle pure nitric acid .....	50
2 lbs. bi-carbonate soda ....	20
1 lb. carbonate of potash .....	20
$\frac{1}{4}$ lb. cyanide of potash .....	25
$\frac{1}{4}$ lb. borax glass .....	50
2 lbs. flour .....	20
1 lb. argol.....	18
2 lbs. nitre (nitrate potash) .....	30
2 lbs. litharge .....	25

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1 lb. charcoal, pulverized .....	25
1 lb. silica.....	20
$\frac{1}{2}$ lb. sheet lead .....	25
1 lb. granulated lead .....	40
2 lbs. bone-ash .....	36
$\frac{1}{2}$ oz. pure silver foil.....	75

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\$179 64

Note-books, gummed labels, tin boxes for dry reagents, bottles, bags or boxes for samples, etc., according to fancy of purchaser.

# SECTION III.

## TABLES.

### MULTIPLICATION TABLE FOR GOLD AND SILVER.

SILVER.		GOLD.	
OUNCES.	VALUE.	OUNCES.	VALUE.
1.....	\$1 29	1.....	\$20 67
2.....	2 58	2.....	41 34
3.....	3 87	3.....	62 01
4.....	5 16	4.....	82 68
5.....	6 45	5.....	103 35
6.....	7 74	6.....	124 02
7.....	9 03	7.....	144 69
8.....	10 32	8.....	165 36
9.....	11 61	9.....	186 03

NOTE.—The above table is more relative than actual. \$20.00 is commonly used as a factor for gold, and for silver the value per ounce fluctuates with the market.

TABLE OF VALUES OF GOLD AND SILVER.

WEIGHT.	Of Gold is worth	Of Silver is worth
1 grain Troy.....	\$0.0430	\$0.0026
1 pennyweight Troy = 24 grains Troy.....	1.0335	0.0646
1 ounce Troy = 20 pennyweights Troy = 480 grains Troy .....	20.6718	1.2929
1 ounce Avoirdupois = 437½ grains Troy.....	18.8415	1.1784
1 pound Troy = 12 ounces Troy = 240 pennyweights Troy = 5,760 grains Troy.....	248.0620	15.5151
1 pound Avoirdupois = 16 ounces Avoirdupois = 7,000 grains Troy.....	301.4642	18.8551
1 ton Avoir. = 2,000 pounds Avoir. = $\left\{ \begin{array}{l} 29,166 \text{ ounces Troy} \\ 32,000 \text{ ounces Avoir.} \end{array} \right\} =$ 14,000,000 grains Troy.....	602,928.4660	37,710.3846

NOTE.—The above values are figured on the basis of \$20.67 per Troy oz. for gold, and \$1.29 for silver. Were the factors made \$20 for gold, and the fluctuation prices of \$1.10 and \$1.15 for silver, the values given would be varied considerably.

## TABLES OF WEIGHTS.

## AVOIRDUPOIS WEIGHT.

16 Drams=1 Ounce.

16 Ounces= 1 Pound.

28 Pounds= 1 Quarter.\*

4 Quarters=1 Hundred weight.

20 Hundred weight=1 Ton of 2240 pounds.

## AVOIRDUPOIS WEIGHT.

1 dram.

1 ounce=16 drams.

1 pound=16 ounces=256 drams.

1 quarter=28 pounds=448 ounces=7168 drams.

1 h'dwt=4 quarters=112 pounds=1792 ounces=28672 drams.

1 ton=20 h'dwt=80 quarters=2240 pounds=35840 ounces=573440 drams.

## AVOIRDUPOIS WEIGHT.

25 Pounds=1 Quarter.

4 Quarters=1 Hundred weight.

20 Hundred weight=1 Ton of 2000 pounds.

## AVOIRDUPOIS WEIGHT.

1 quarter=25 pounds=400 ounces=6400 drams.

\* In some parts of the United States.

1 h'dwt=4 quarters=100 pounds=1600 ounces=  
25600 drams.

1 ton=20 h dwt=80 quarters=2000 pounds=32000  
ounces=512000 drams.

#### TROY WEIGHT.

24 Grains=1 Pennyweight.

20 Pennyweights=1 Ounce.

12 Ounces=1 Pound.

#### TROY WEIGHT.

1 grain.

1 pennyweight=24 grains.

1 ounce=20 pennyweights=480 grains.

1 pound=12 ounces=240 pennyweights=5760 grains.

#### APOTHECARIES' WEIGHT.

20 Grains=1 Scruple.

3 Scruples=1 Dram.

8 Drams=1 Ounce.

12 Ounces=1 Pound.

#### APOTHECARIES' WEIGHT.

1 grain.

1 scruple=20 grains.

1 dram=3 scruples=60 grains.

1 ounce=8 drams=24 scruples=480 grains.

1 pound=12 ounces=96 drams=288 scruples=5760  
grains.



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1 pound, Troy,	=5760 grains.
1 pound, Apothecaries',	=5760 grains.
1 pound, Avoirdupois,	=7000 Troy grains.

## FRENCH OR METRIC SYSTEM OF WEIGHTS.

1 Milligramme	= .001	of a Gramme.
1 Centigramme	= .01	" "
1 Decigramme	= .1	" "
1 Gramme	= 1	Gramme.
1 Decagramme	= 10	Grammes.
1 Hectogramme	= 100	"
1 Kilogramme	= 1000	"
1 Myriagramme	= 10000	"

or

10 Milligrammes (mgrs)	= 1 Centigramme (cgr).
10 Centigrammes	= 1 Decigramme (dgr).
10 Decigrammes	= 1 Gramme (grm).
10 Grammes	= 1 Decagramme (dkgr).
10 Decagrammes	= 1 Hectogramme (hgr).
10 Hectogrammes	= 1 Kilogramme (kgr).
10 Kilogrammes	= 1 Myriagramme (myrgr).

1 mgr.

1 cgr. = 10 mgrs.

1 dgr. = 10 mgrs. = 100 mgrs.

1 grm. = 10 mgrs. = 100 mgrs. = 1,000 mgrs.

1 dkgr. = 10 grms. = 100 mgrs. = 1,000 mgrs. = 10,000 mgrs.

1 hgr.=10 dkgrs.=100 grms.=1,000 dgrs.=10,000  
cgrs.=100,000 mgrs.

1 kgr.=10 hgrs.=100 dkgrs.=1,000 grms.=10,000  
dgrs.=100,000 cgrs.=1,000,000 mgrs.

1 myrgr.=10 kgrs.=100 hgrs.=1,000 dkgrs.=10,000  
grms.=100,000 dgrs.=1,000,000 cgrs.=10,000,000  
mgrs.

1 gramme=15.43235 Troy grains.

EQUIVALENTS OF SOME OF THE ENGLISH AND FRENCH  
WEIGHTS.\*

<i>Troy Grains.</i>		<i>Grammes.</i>
1	=	.064798
2	=	.129597
3	=	.194396
4	=	.259195
5	=	.323994
6	=	.388793
7	=	.453592
8	=	.518391
9	=	.583190

<i>Grammes.</i>		<i>Troy Grains.</i>
1	=	15.43235
2	=	30.86470
3	=	46.29705
4	=	61.72940
5	=	77.16175
6	=	92.59410
7	=	108.02645
8	=	123.45880
9	=	138.89115

\* T. Eggleston's Tables of Weights, Measures, Coins, etc.,  
p. 24.

ASSAY TON EQUIVALENTS IN GRAMMES, TROY  
GRAINS, AND TROY OUNCES.

Based on 1 gramme=15.43235 Troy grains; hence 1 assay ton  
or 29.166 grammes=15.43235 × 29.166=450.09992 Troy grains.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
0.05	1.458	22.504	.....
0.10	2.916	45.009	.....
0.15	4.374	67.514	.....
0.20	5.833	90.019	.....
0.25	7.291	112.524	.....
0.30	8.749	135.029	.....
0.35	10.208	157.534	.....
0.40	11.666	180.039	.....
0.45	13.124	202.544	.....
0.50	14.583	225.049	.....
0.55	16.041	247.554	.....
0.60	17.499	270.059	.....
0.65	18.958	292.564	.....
0.70	20.416	315.069	.....
0.75	21.874	337.574	.....
0.80	23.333	360.079	.....
0.85	24.791	382.584	.....
0.90	26.249	405.089	.....
0.95	27.708	427.594	.....
1.00	29.166	450.099	.....

## ASSAY TON EQUIVALENTS — CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
1.05	30.624	472.604	.....
1.10	32.083	495.109	1.032
1.15	33.541	517.614	1.078
1.20	34.999	540.119	1.125
1.25	36.458	562.624	1.173
1.30	37.916	585.129	1.219
1.35	39.374	607.634	1.266
1.40	40.833	630.139	1.313
1.45	42.291	652.644	1.360
1.50	43.749	675.149	1.407
1.55	45.208	697.654	1.453
1.60	46.666	720.159	1.500
1.65	48.124	742.664	1.547
1.70	49.583	765.169	1.594
1.75	51.041	787.674	1.641
1.80	52.499	810.179	1.667
1.85	53.958	832.684	1.735
1.90	55.416	855.189	1.782
1.95	56.874	877.694	1.829
2.00	58.333	900.199	1.875

## ASSAY TON EQUIVALENTS — CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
2.05	59.791	922.704	1.922
2.10	61.249	945.209	1.969
2.15	62.708	967.714	2.016
2.20	64.166	990.219	2.063
2.25	65.624	1012.724	2.110
2.30	67.083	1035.229	2.157
2.35	68.541	1057.734	2.204
2.40	69.999	1080.239	2.250
2.45	71.458	1102.744	2.297
2.50	72.916	1125.249	2.344
2.55	74.374	1147.754	2.391
2.60	75.833	1170.259	2.438
2.65	77.291	1192.764	2.485
2.70	78.749	1215.269	2.531
2.75	80.208	1237.774	2.579
2.80	81.666	1260.279	2.626
2.85	83.124	1282.784	2.672
2.90	84.583	1305.289	2.719
2.95	86.041	1327.794	2.766
3.00	87.499	1350.299	2.813

## ASSAY TON EQUIVALENTS—CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
3.05	88.958	1372.804	2.860
3.10	90.416	1395.309	2.905
3.15	91.874	1417.814	2.954
3.20	93.333	1440.319	3.001
3.25	94.791	1462.824	3.048
3.30	96.249	1485.329	3.094
3.35	97.708	1507.834	3.141
3.40	99.166	1530.339	3.188
3.45	100.624	1552.844	3.235
3.50	102.083	1575.349	3.282
3.55	103.541	1597.854	3.329
3.60	104.999	1620.359	3.376
3.65	106.458	1642.864	3.423
3.70	107.916	1665.369	3.470
3.75	109.374	1687.874	3.516
3.80	110.833	1710.379	3.563
3.85	112.291	1732.884	3.610
3.90	113.749	1755.389	3.657
3.95	115.208	1777.894	3.704
4.00	116.666	1800.399	3.751

## ASSAY TON EQUIVALENTS—CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
4 05	118.124	1822.904	3.798
4.10	119.583	1845.409	3.845
4.15	121.041	1867.914	3.891
4.20	122.499	1890.419	3.938
4.25	123.958	1912.924	3.985
4.30	125.416	1935.429	4.032
4.35	126.874	1957.934	4.079
4.40	128.333	1980.439	4.126
4.45	129.791	2002.944	4.173
4.50	131.249	2025.449	4.220
4.55	132.708	2047.954	4.267
4.60	134.166	2070.459	4.313
4.65	135.624	2092.964	4.360
4.70	137.083	2115.469	4.407
4.75	138.541	2137.974	4.454
4.80	139.999	2160.479	4.500
4.85	141.458	2182.984	4.548
4.90	142.916	2205.489	4.595
4.95	144.374	2227.994	4.642
5.00	145.833	2250.499	4.689



## ASSAY TON EQUIVALENTS — CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
5.05	147.291	2273.004	4.735
5.10	148.749	2295.509	4.782
5.15	150.208	2318.014	4.829
5.20	151.666	2340.519	4.876
5.25	153.124	2363.024	4.923
5.30	154.583	2385.529	4.970
5.35	156.041	2408.034	5.017
5.40	157.499	2430.539	5.064
5.45	158.958	2453.044	5.111
5.50	160.416	2475.549	5.157
5.55	161.874	2498.054	5.204
5.60	163.333	2520.559	5.251
5.65	164.791	2543.064	5.298
5.70	166.249	2565.569	5.345
5.75	167.708	2588.074	5.392
5.80	169.166	2610.579	5.439
5.85	170.624	2633.084	5.486
5.90	172.083	2655.589	5.532
5.95	173.541	2678.094	5.579
6.00	174.999	2700.579	5.626

## ASSAY TON EQUIVALENTS — CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in TroyOunces.
6.05	176.458	2723.084	5.673
6.10	177.916	2745.589	5.720
6.15	179.374	2768.094	5.767
6.20	180.833	2790.599	5.814
6.25	182.291	2813.104	5.861
6.30	183.749	2835.609	5.908
6.35	185.208	2858.114	5.954
6.40	186.666	2880.619	6.001
6.45	188.124	2903.124	6.048
6.50	189.583	2925.629	6.095
6.55	191.041	2948.134	6.142
6.60	192.499	2970.639	6.189
6.65	193.958	2993.144	6.236
6.70	195.416	3015.649	6.283
6.75	196.874	3038.154	6.329
6.80	198.333	3060.659	6.376
6.85	199.791	3083.164	6.423
6.90	201.249	3105.669	6.470
6.95	202.708	3128.174	6.517
7.00	204.166	3150.679	6.564

## ASSAY TON EQUIVALENTS — CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
7.05	205.624	3173.184	6.611
7.10	207.083	3195.689	6.658
7.15	208.541	3218.194	6.705
7.20	209.999	3240.699	6.751
7.25	211.458	3263.204	6.798
7.30	212.916	3285.709	6.845
7.35	214.374	3308.214	6.892
7.40	215.833	3330.719	6.939
7.45	217.291	3353.224	6.986
7.50	218.749	3375.729	7.033
7.55	220.208	3398.234	7.080
7.60	221.666	3420.739	7.127
7.65	223.124	3443.244	7.173
7.70	224.583	3465.749	7.220
7.75	226.041	3488.254	7.267
7.80	227.499	3510.759	7.314
7.85	228.958	3533.264	7.361
7.90	230.416	3555.769	7.408
7.95	231.874	3578.274	7.455
8.00	233.333	3600.779	7.502

## ASSAY TON EQUIVALENTS—CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
8.05	234.791	3623.284	7.549
8.10	236.249	3645.789	7.595
8.15	237.708	3668.294	7.642
8.20	239.166	3690.799	7.689
8.25	240.624	3713.304	7.736
8.30	242.083	3735.809	7.783
8.35	243.541	3758.314	7.830
8.40	244.999	3780.819	7.877
8.45	246.458	3803.324	7.924
8.50	247.916	3825.829	7.970
8.55	249.374	3848.334	8.017
8.60	250.833	3870.839	8.064
8.65	252.291	3893.344	8.111
8.70	253.749	3915.849	8.158
8.75	255.208	3938.354	8.205
8.80	256.666	3960.859	8.252
8.85	258.124	3983.364	8.299
8.90	259.583	4005.869	8.346
8.95	261.041	4028.374	8.392
9.00	262.449	4050.879	8.439

## ASSAY TON EQUIVALENTS — CONTINUED.

Assay Tons.	Value in Grammes.	Value in Troy Grains.	Value in Troy Ounces.
9.05	263.958	4073.384	8.486
9.10	265.416	4095.889	8.533
9.15	266.874	4118.394	8.580
9.20	268.333	4140.899	8.627
9.25	269.791	4163.404	8.674
9.30	271.249	4185.909	8.721
9.35	272.708	4208.414	8.768
9.40	274.166	4230.919	8.814
9.45	275.624	4253.424	8.861
9.50	277.083	4275.929	8.908
9.55	278.541	4298.434	8.955
9.60	279.999	4320.939	9.002
9.65	281.458	4343.444	9.049
9.70	282.916	4365.949	9.096
9.75	284.374	4388.454	9.143
9.80	285.833	4410.959	9.189
9.85	287.291	4433.464	9.236
9.90	288.749	4455.969	9.283
9.95	290.208	4478.474	9.330
10.00	291.666	4500.979	9.377



# INDEX.

## A.

- ACETATE OF LEAD, re-agent, 105.  
 ACICULAR BISMUTH, mineral, 262.  
 ACID FLUX, silica, 101.  
 ACID, HYDROCHLORIC (muriatic), 109.  
 ACID, NITRIC; re-agent, 107, 110; preparation of various strengths, 162; to free from chlorine, 107.  
 ACID, SULPHURIC, re-agent, 113.  
 AIKINITE, mineral, 258, 262.  
 ALASKAITE, mineral, 258, 265.  
 ALCOHOL, re-agent, 108.  
 ALDEN CRUSHER, 19.  
 ALGODONITE, mineral, 261, 262.  
 ALPHABETS AND FIGURES, steel, 90.  
 ALTAITE, mineral, 258, 261, 265.  
 ALUMINA AND LEAD PHOSPHATE, 267.  
 ALUMINIUM, element, 11.  
 AMALGAMATION, assay, 221; mortar, 91, 223.  
 AMALGAM, GOLD, mineral, 257.  
 AMMONIA, aqua (caustic, hydrate, water), 108; carbonate, 94, 99; citrate, 109.  
 ANALYSIS, books on, 269, 270; copper ores, 210; definition, 13; re-agents for, 108.  
 ANGLESITE, mineral, 265.  
 ANNEALING CUPS, 76, 242; plate, 76, 241.  
 ANTIMONIAL red silver ore, 200; silver, 130, 259; sulphide of silver and lead, 259, 266.  
 ANTIMONY, and lead sulphide, 265; and silver sulphide, 130, 259, 260; arsenic and silver sulphide, 130, 259; bismuth and lead sulphide, 266; copper and lead sulphide, 262, 265; cupel color, 247; element, 11; native, 261; oxide, 260; vapors, 246.  
 ANYILS, and method of mounting, 85.  
 APOTHECARIES' weights, tables of, 282.  
 APPARATUS, for analysis and assaying, 17; glass and porcelain, 77; miscellaneous, 81; sulphuretted hydrogen, 113; used in furnace, 68.  
 ARGENTIFEROUS gold, 257, 259; gray copper, 131; lead ores, 131; ores, 131; pyrites, 132; zinc blende, 132.  
 ARGENTIC NITRATE, re-agent, 110.  
 ARGENTITE, mineral, 258.  
 ARGOL, re-agent, 93, 98; reducing power, 121.

- "ARRASTRE," 91, 223.  
 ARSENATE, LEAD, mineral, 266.  
 ARSENIC, antimony and silver sulphide, 130, 259; cupel color, 247; element, 11; native, 258, 261; vapors, 246.  
 ARSENICAL, copper, 263; silver ore, 130, 259.  
 ARSENIDE, COPPER, mineral, 262, 263, 265.  
 ARSENOPIRYTE, mineral, 129, 258, 261.  
 ASSAY, amalgamation, 221; base bullion, 243; certificate, 275; chlorination, 234; copper, 181; galena, 186; gold and silver, 132; gold bullion, 239; lead, 186; ton equivalents, 286; ton weights, 40; ton weights, explanation, 41.  
 ASSAYING, apparatus, 17; books on, 273; definition, 13; dry re-agents for, 93; free gold and silver ores, 203; of various minerals in an ore, 201; outfit, 276; re-agents used in, 93; wet re-agents used in, 106.  
 ATACANITE, mineral, 262.  
 ATTWOOD, blow pipe assaying, 271; reference to, 227.  
 AURICHALCITE, mineral, 262.  
 AURIFEROUS SULPHURETS, 129.  
 AUSTIN, L. S., references to, 134, 245.  
 AVERAGE SAMPLES, obtaining of, 134.  
 AVOIRDUPOIS WEIGHTS, tables of, 281.  
 AZURE COPPER ORE (azurite), 181, 262.
- ## B
- BALANCES, Becker's, 29, 33-4-5; bullion, 32; for weighing gold and silver beads, 33; Oertling's, 35; Troemner's, 29, 30, 33-4-5.  
 BALLING'S Works on Assaying, 273.  
 BARIUM, chloride (muriate), re-agent, 109; element, 11.  
 BARKER'S ELEMENTARY CHEMISTRY, 268.  
 BARNARD'S METRIC SYSTEM, 274.  
 BARNHARDITE, mineral, 261, 262.  
 BASE BULLION, assay, 243; sampling, 245.  
 BASIC FLUX, nitre, 99.  
 BATEA, 227.  
 BATHS, sand, 87.  
 BATTERSEA, crucibles, 70; furnaces, 53; muffles, 68; roasting dishes, 71; scorifiers, 72.  
 BATTERY, Bunsen carbon, 215; "gravity," 217.  
 BEADS, gold and silver, balance for weighing, 32; inquarting, 164; parting, 141, 161; weighing, 141, 160.  
 BEAKERS, glass, 80.  
 BEAUFAY CRUCIBLES, 69, 70.  
 BECKER'S DULLION BALANCES, 33-4-5; pulp scales, 28.



- BI-CARBONATE OF SODA, re-agent 93, 94; properties, 94.  
 BI-CHROMATE OF POTASH. re-agent, 108.  
 BISMUTH, acicular (cupreous), 262; cupel color, 247; element, 11; lead and antimony sulphide, 266; native, 258, 261; silver, 260, 267; silver and lead sulphide, 258, 260, 265, 267.  
 BISMUTHINITE, mineral, 258.  
 BI-TARTRATE OF POTASH, re-agent, 98, 121.  
 BLACK flux substitute, 93, 98; copper or oxide of copper, 180, 264; oxide of manganese, 108; silver, 260; tellurium. 257, 267.  
 BLAKE CRUSHER, 19.  
 BLENDE, 129; argentiferous, 132.  
 "BLICKING," 156.  
 "BLOSSOMING," 157.  
 BLOTING PAPER, 83.  
 BLOW-PIPE, 88; analysis, books on, 271.  
 BLUE carbonate of copper (blue malachite, mountain blue), 181, 262.  
 BLUE COPPER, mineral, 263.  
 BLUE VITRIOL, mineral, 263.  
 BODEMANN & KERL's works on assaying, 273; reference to, 184.  
 BOILING FLASKS, 79.  
 BONE-ASH, 113.  
 BOOKS, note, 81, 133; list of useful, 268.  
 BORAX GLASS. preparation of, 97; re-agent, 93, 96.  
 BORNITE, mineral, 261, 262.  
 BORON, element, 11.  
 BOTTLE, WASH, 73.  
 BOTTLES, re-agent, 77: sample, 77, 134.  
 BOULANGERITE, mineral, 261, 265.  
 BOURNONITE, mineral, 262, 265.  
 BOXES, SAMPLE, 82, 134.  
 BRIEF SCHEME FOR SILICA, iron and manganese, 254.  
 "BRIGHTENING," 156.  
 BRITTLE SILVER-ORE, mineral, 130, 260.  
 BROCHANTITE, mineral, 262.  
 BROMIC SILVER (bromide of silver, bromyrite), 131, 258.  
 BROMINE, element, 11.  
 BROWN'S ASSAY FURNACE, 55.  
 BRUSHES, 31, 39, 83.  
 BRUSH'S MINERALOGY, 271.  
 BUCKING HAMMER, 22.  
 BUFFALO DENTAL MFG. Co., 44, 46.  
 BULLION balances, 32; base, assay of, 243; base, sampling of, 245; gold, assay of, 239; Silver, Report upon Wastage of, 239.  
 BUNSEN battery, 215; burners, 87.  
  
 C  
 CADMIUM, element, 11.  
 CÆSIUM, element, 12.  
 CAIRNS' QUANTITATIVE ANALYSIS, 269.

- CALAVERITE, mineral, 257, 261.  
CALCIUM, chloride, 37, 113; element, 11; hydroxide, 110.  
CALC-SPAR, mineral, 178.  
CALCULATIONS in scorification process, 141, 166.  
CALEDONITE, mineral, 263, 265.  
CALLON'S LECTURES ON MINING, 272.  
CAPSULES, porcelain, 78.  
CARBON, element, 11.  
CARBONATE of ammonia, re-agent, 94, 99; of copper, blue and green, mineral, 181, 262, 264; of lead, mineral, 132, 186, 265; of lead, re-agent, 105; of potash, re-agent, 93, 95; of zinc and copper, mineral, 262.  
"CARBONATE ORES," 129.  
CARBONATES, tests for, 249.  
CARPENTER'S MINING CODE, 274.  
CARROLLITE, mineral, 263.  
CASE, GLASS, for pulp-scale, 29.  
CASSEROLE, 81.  
CAUSTIC ammonia, 108; lunar, 110; potash, 108.  
CERARGYRITE, mineral, 259.  
CERIUM, element, 12.  
CERTIFICATE OF ASSAY, Form for, 275.  
CERUSE, re-agent, 105.  
CERUSSITE, mineral, 132, 186, 261, 265.  
CHALCANTHITE, mineral, 263.  
CHALCOCITE, mineral, 181, 263.  
CHALCOPYRITE, mineral, 181, 258, 261, 263.  
CHALK, dry, 114; wash, 114.  
CHAMOIS SKIN, 92.  
CHARCOAL, WOOD, charge for testing, 122; properties of, 99; re-agent, 94, 99; reducing power, 122.  
CHARGES, crucible for galena, 179; crucible for quartz, sand or "dry" ores, 171; crucible, large, 175; for antimonial and arsenical ores, 169; for argol, 121; for basic ores, 178; for charcoal, 122; for chlorides, 169; for copper mattes, 169; for copper oxides and carbonates, 183; for copper sulphides, 183; for cream of tartar, 121; for granulated lead, 118; lead carbonates, 194; for lead in galena, 186, 189, 190, 191, 193; for lead oxides, 195; for lime or baryta gangue, 169; for litharge, 116; for native copper, 182; for nitre, 122; for ordinary scorifications, 168; for oxides of iron, 170; for sulphurets, 169; for tellurides, 169; for testing ores, 124; in scorification process, 167; Low's, 177; preparation of, 141; Ricketts', 122, 124, 176, 184, 191; scorification for copper, 168; scorification for galena, 170; Stone's, 178.  
"CHECKING," 75.  
CHEMICAL TECHNOLOGY, Wagner's, 268.  
CHEMISTRY, Barker's, 268; gen-

- eral, books on, 268; Miller's, 268; reference books on, 268; Roscoe and Schorlemmer, 268; Roscoe's Elementary, 269; theoretical text-books on, 268; Watts' Dictionary, 268.
- CHLORIDE, and phosphate of lead, 267; baric, 109; calcic, 37, 113; mercuric, 110; of silver, 131, 259; of sodium, 99; stannous, 111.
- "CHLORIDE ORES," 131.
- CHLORINATION assay of gold ores, 234; test for silver, 237.
- CHLORINE, element, 11; in distilled water, 106; to free nitric acid from, 107.
- CHLORO-BROMIDE OF SILVER, mineral, 259.
- CHROMATE OF COPPER AND LEAD, mineral, 265, 267
- CHROMIUM, element, 11; color on cupel, 248.
- CHRYSOCOLLA, mineral, 263.
- CITRATE OF AMMONIUM, re-agent, 109.
- CLASSEN'S QUANTITATIVE ANALYSIS, 269.
- CLASSIFICATION OF SILVER ORES, 130.
- CLAY CRUCIBLES, 70; lute, 114.
- CLOCK-GLASSES, 78.
- CLOTH, oil and rubber, 82.
- COBALT, color on cupel, 248; element, 11; nickel and copper sulphide, 263.
- COFFEE-MILL, 98.
- COLD CHISEL, 91.
- COLLINS' MINING AND QUARRYING, 272.
- COLORADO crucibles, 71; minerals, 267.
- COLORADOITE, mineral, 258, 261.
- COLOR tests, cupel, 247; scorification, 246; scorifier, 247.
- COLUMBIUM, element, 12.
- COMMON SALT, re-agent, 94, 99.
- COPPER, analysis, methods, 210; and iron sulphide, sulphuret or pyrites, 129, 132, 181, 262, 263; and lead chromate, 265, 267; and silver sulphide or sulphuret, 131, 260, 264; and uranium phosphate, 264; and zinc carbonate, 262; argentiferous gray, 131; arsenical, 263; arsenide, 262, 263, 265; assay, 181; azure, 262; black oxide, 180, 264; blue, 263; blue carbonate, 181, 262; blue malachite, 262; carbonates, 182; cobalt and nickel sulphide, 263; color on cupel, 248; color on scorifier, 247; element, 11; glance, 263; gray, 129, 181, 260, 264; green, 264; green carbonate, 181, 264; indigo, 263; lead and antimony sulphide, 262, 265; metallic, 110; metallurgy, 272; minerals in the U. S., 262; muriate, 262; native, 180, 261, 264; native, assay, 182; occurrence, 180; oxides, 182, 264; oxides, assay, 182; oxy-chloride, 262; phos-

- phate, 264; purple, 262; pyrites, 263; pyritous, 263; red oxide, 180, 263; silicate, 263; spatulas, 27; sulph-arsenite, 263, 264; sulphate, 262, 263; sulphides or sulphurets, 181, 260, 263; sulphides, assay, 183; tests for, 251; uranite, 264; variegated, 262; vitreous, 263; vitriol, 263; volumetric analysis, 220.
- COPPERAS, re-agent, 111.
- COPP'S AMERICAN MINING CODE, 274.
- CORNWALL'S BLOW-PIPE ANALYSIS, 271.
- CORROSIVE SUBLIMATE, re-agent, 110.
- COTTA'S TREATISE ON ORE DEPOSITS, 270.
- COVELLITE, mineral, 263.
- CREAM OF TARTAR, re-agent, 93, 98; reducing power, 121.
- CRUCIBLE CHARGES, for argol, 121; for charcoal, 122; for copper carbonates, 183; for copper oxides, 183; for copper sulphides, 184; for cream of tartar, 121; for gold and silver in galena, 179; large, 175; for lead carbonates, 195; for lead in galena, 186, 189, 190, 191, 193; for lead oxides, 195; for litharge, 116; for native copper, 182; for nitre, 122; for quartz, sand or "dry" ores, 171; for testing ores, 124; Low's, 177; Ricketts', 122, 124, 176, 184, 191; Stone's, 178.
- CRUCIBLE PROCESS, 133, 170; directions for operating, 171; for gold and silver ores, 133, 170; theory of, 174.
- CRUCIBLE TONGS, 59.
- CRUCIBLES, alumina, 69; Battersea, 70; black lead (graphite or plumbago), charcoal-lined, 69; clay, 70; "Colorado," 71; French clay or "Beaufay," 69, 70; gold, 69; "Gramme," 71; Hessian, iron, magnesia, platinum, 69; porcelain, 69, 78; quick lime, 69; round, 70; sand, 70; silver, 70; triangular, 70.
- CRUSHERS, Alden, Blake, Forster, Lipsey, 18, 19.
- CUPEL, color tests, 247; moulds, 88; rake, 64; shovel, 64; tongs, 62.
- CUPELLATION, 141, 152.
- CUPELS, 73; directions for making, 74.
- CUPREOUS, bismuth, 262; sulphato-carbonate of lead, 263, 265.
- CUPRIC OXIDE, mineral, 264.
- CUPRITE (or cuprous oxide), mineral, 180, 263.
- CUPS, annealing, 76.
- CYANIDE OF POTASH, properties, 96; re-agent, 93, 95.
- CYCLOPÆDIA, Johnson's New Universal, 268.

## D

DANA, Manual of Geology, 270;  
Manual of Mineralogy, 271;  
reference to, 267; System of  
Mineralogy, 267, 270; Text-  
book of Geology, 270.  
DARK RED SILVER ORE, 130, 260.  
DAVYUM, element, 12.  
DECHENITE, mineral, 265.  
DECIPIUM, element, 12.  
DEFINITIONS, of analysis, 13; of  
assaying, 13.  
DENDRITIC SILVER, 259.  
DENVER FIRE CLAY CRUCIBLES,  
71.  
DESCLOIZITE, mineral, 265.  
DESULPHURIZING ACTION, of bi-  
carbonate of soda, 94; carbon-  
ate of ammonia, 99; cyanide  
of potash, 96; iron, 105, 189;  
litharge, 104.  
DETERMINATION OF moisture in  
an ore, 255; oxidizing power of  
nitre, 115, 122; reducing pow-  
ers of argol, 121; charcoal, 122;  
cream of tartar, 121; ores, 116,  
123; reducing agents, 115, 121.  
DI-CBROMATE, potassic, 108.  
DICTIONARY OF CHEMISTRY, Watts',  
268.  
DIDYMIUM, element, 12.  
DIRECTIONS FOR bullion balances,  
37; crucible process, 171; cupel-  
lation, 154; filtering, 212;  
making cupels, 74; operating  
Hoskins' furnace, 48; operating

Myers' furnace, 52; sampling  
ores, 134.

DISHES, ROASTING, 71.

DISTILLED WATER, chlorine in,  
106; re-agent, 106.

DIVIDERS, 24.

DOMYKITE, mineral, 263.

DOUGLAS & PRESCOTT'S QUALITA-  
TIVE ANALYSIS, 269.

DRY RE-AGENTS, list of, 93.

DYSCRASITE, mineral, 259.

## E

EGGLESTON, reference to, 285.

EGGLESTON'S WEIGHTS, MEASURES  
AND COINS, 274.

ELDERBORST'S BLOW-PIPE ANAL-  
YSIS, 271.

ELECTRUM, mineral, 257, 259.

ELEMENTS, lists of, 11, 12.

ELEMENTS OF CHEMISTRY, MIL-  
LER'S, 268.

ELIOT AND STORER'S QUALITATIVE  
ANALYSIS, 269.

EMBOLITE, mineral, 259.

ENARGITE, mineral, 261, 263.

ENGINEERING AND MINING JOUR-  
NAL, references to, 134, 206,  
243.

ENGLISH AND FRENCH WEIGHTS,  
equivalents of, 285.

ERBIUM, element, 12.

ERUBESCITE, mineral, 262.

EUSTIS, W. E. C., reference to, 211.

EXPLANATION of assay ton  
weights, 41.

## F

"FEATHERING," 155.  
 FERRIC SESQUIOXIDE, 114.  
 FERROCYANIDE, POTASSIC, re-agent, 109.  
 FERRO TELLURITE, mineral, 258, 261.  
 FERROUS sulphate, re-agent, 111; sulphide, re-agent, 111.  
 FILINGS, IRON, re-agent, 105.  
 FILTERING, directions for, 212.  
 FILTER paper, 83; stands, 91.  
 FIRE CLAY, in clay lute, 114.  
 "FLASHING," 156.  
 FLASKS, 80; parting or boiling, 79.  
 FLETCHER'S GAS FURNACE, 44, 191.  
 FLOORS, MUFFLE, 69.  
 FLOUR, re-agent, 93, 98.  
 FLOUR GOLD, 129, 257.  
 FLUORINE, element, 11.  
 FLUOR SPAR. mineral, 178.  
 FLUXES, acid 101; basic, 99; bicarbonate of soda, 93, 24; black flux substitute, 93, 98; borax, 93, 96; carbonate of potash, 93, 95; cyanide of potash, 93, 95; flour, 93, 98; glass, 101; litharge, 94, 103; metallic, 104; neutral, 96; nitre, 99; sand, 101; scales for, 28; silica, 101; Stone's universal, 178.  
 FLUXING POTS, 70.  
 FOIL, lead, re agent, 102; lead, silver in, 120; silver, re-agent, 105.

FOLIATED TELLURIUM, mineral, 257, 267.  
 FORM FOR CERTIFICATE OF ASSAY, 275.  
 FORSTER CRUSHER, 19.  
 FOYE'S MINERAL TABLES, 271.  
 FRAZER'S MINERAL TABLES, 271.  
 FREE GOLD, 129, 257; assay of in ores, 203.  
 FREE SILVER, 259; assay of in ores, 203.  
 "FREEZING," 159.  
 FREIESLEBENITE, mineral, 259, 266.  
 FRENCH CLAY CRUCIBLES, 69.  
 FRENCH OR METRIC WEIGHTS, 39, 40; equivalents in English weights, 285; tables of, 283.  
 FRESSENIUS' Qualitative and Quantitative Analysis, 255, 269; reference to, 255.  
 FRYING PAN, 87.  
 FUEL, metallurgy, Percy, 272.  
 FUNNELS, glass, 80; separatory, 80, 236.  
 FURNACES, 42; apparatus used in 68; Battersea, 53; Brown's, 55; Fletcher's, 44; Hoskins', 46; Judson's, 54; Myers', 49; tools for, 59; using gaseous fuel, 43; using liquid fuel, 46, using solid fuel, 53.

## G

GALENA or galenite, 185, 258, 261, 266; crucible charge for,

- 179; iron in assay of, 105, 189; methods for, 186; scorification charge for, 170.
- GALLIUM, element, 12.
- GAS FURNACES, Fletcher's, 44, 191.
- GAS, hydrogen sulphide, reagent, 111.
- GAUZE, wire, 87.
- "GEM-PLATE," 66.
- GENERAL chemistry, books on, 268; qualitative and quantitative analysis, books on, 269; science, books on, 268.
- GEOCRONITE, mineral, 261, 266.
- GEOLOGY, books on, 270.
- GLANCE, copper, 263; lead, 131; silver, 130, 258; silver-copper, 131, 260, 264.
- GLASS and porcelain apparatus, 77; beakers, 80; borax, 93, 96; borax, preparation, 97; case for pulp-scales, 29; flasks, 80; funnels, 80; magnifying, 90; mortars, 81; pipettes, 81; reagent, 101; stirring-rods, 80; spatulas, 27.
- GLASSES, watch or clock, 31, 78.
- GLUCINUM, element, 12.
- GLYCERINE, for sulphuretted hydrogen water, 113.
- GOLD, amalgam, 257, 261; and lead telluride, 257, 267; argenteriferous, 257, 259; assaying of, 129, 132; assaying of free, 203; bullion assay, 239; chlorination assay, 234; element, 11; crucible process, 170; flour, free, leaf, native, nugget, wire, 129, 257; in silver foil, 105; Lock's work on, 272, minerals in U. S., 257; minerals likely to carry, 258; multiplication table, 279; native, 129, 257, 261; occurrence, 129; pan test or "panning," 225; residues, weighing of, 141, 165; telluride, 257; testing of silver-foil for, 105; table of values of, 280; washing pans, 91, 227.
- "GOLD WEIGHTS," 42, 240.
- GOLD AND SILVER and lead telluride, 257, 266; assaying, 129, 132; beads, balances for weighing, 32; beads, weighing of, 141, 160; calculations, 141, 166; crucible process, 170; cupellation, 141, 152; inquartation, 141, 164; metallurgy, books on, 272; multiplication table, 279; occurrence, 129; parting, 141, 161; preparation of charge 141; preparation of sample, 133; residue, weighing, 141, 165; roasting, 142; scorification charges, 167; scorification process, 139; table of values, 280; telluride, 257, 259, 260.
- GRAIN WEIGHTS, 41.
- "GRAMME" CRUCIBLES, 71
- GRAMME WEIGHTS, 39, 40.
- GRANULATED LEAD, preparation, 102; re-agent, 94, 102; testing for silver, 118.

GRAPHIC TELLURIUM, mineral, 257, 260.  
 GRAY COPPER, 129, 181, 260, 264; argentiferous, 181.  
 GREEN carbonate of copper, 181, 264; copper ore, 264; lead ore, 266; malachite, 264; mountain, 263, 264; vitriol, 111.  
 GRINDING PLATE, 21: Mr. S. A. Reed's, 23.  
 GUMMED LABELS, 82, 133.

## H.

HAMMERS, 84.  
 HAND-SCALES, 31.  
 HARRISITE, mineral, 263.  
 HART, reference to, 255.  
 HART'S VOLUMETRIC ANALYSIS, 255, 270.  
 HEAVY SPAR, mineral, 178.  
 HEMATITE, re-agent, 114.  
 HENRYITE, mineral, 258, 261, 266.  
 HESSIAN CRUCIBLES, 69.  
 HESSITE, mineral, 258, 259, 261.  
 HOLMIUM, element, 12.  
 HORN, silver, mineral, 130, 259; spatulas, 27; spoons, 28.  
 HOSKINS' ASSAY FURNACE, 46.  
 HYDRATE, ammoniac, re-agent, 108; potassic, re-agent, 108.  
 HYDRIC NITRATE, re-agent, 107.  
 HYDROCHLORIC ACID, re-agent, 109.  
 HYDROGEN; element, 11; sulphide, preparation of as re-agent, 111.

HYDRO-SODIC-CARBONATE, re-agent, 93, 94.  
 HYDRO-POTASSIC-TARTRATE, re-agent, 98.  
 HYDROXIDE, CALCIC, re-agent, 110.  
 HYPOSULPHITE OF SODIUM, re-agent, 109, 238.

## I.

IMPLEMENTS FOR PULVERIZING, SAMPLING, etc., 18.  
 IMPORTANCE OF AVERAGE SAMPLES, 134.  
 IMPORTANT SILVER ORES, 130.  
 INDIGO COPPER, mineral, 263.  
 INDIUM, element, 12.  
 INGOT MOULDS, 90.  
 INQUARTATION, 141, 164.  
 INTRODUCTION, 11.  
 IODIC SILVER (iodide of silver, iodyrite), 131, 259.  
 IODIDE OF POTASH, re-agent, 109.  
 IODINE, element, 11.  
 IRIIDIUM, element, 11.  
 IRON and copper sulphide, sulphuret or pyrites, 129, 132, 262, 263; and silver sulphide, 260; brief scheme for, 254; color on cupel, 248; color on scorifier, 247; desulphurizing action, 105, 189; element, 11; filings, 105; mortars, 18; nails, 94, 105; oxide, 129; re-agent, 94, 105; red oxide, 114; retorts, 92; sulphate, 111; sulphide or sul-



phuret, re-agent, 111; tests for, 251; wire, 94, 105.

IVORY SPATULAS, 27.

## J.

JAMESONITE, mineral, 266.

JOHNSON'S NEW UNIVERSAL CYCLOPÆDIA, 268.

JOSEITE, mineral, 258, 261.

JUDSON'S cupel tongs, 63; furnaces, 54; scorification tongs, 62.

## K.

KERL'S Metallurgy, 271; Works on Assaying, 273.

KOBELLITE, mineral, 266.

KUSTEL, references to, 6, 130, 235, 237, 239; Roasting of Gold and Silver Ores, 6, 130, 272.

## L.

LABELS, gummed, 82, 133.

LABORATORY Manipulation, books on, 270; mill-run, 221.

LAMBORN'S METALLURGY, 272.

LAMPS, 87.

LANARKITE, mineral, 266.

LANTHANUM, element, 12.

LEAD acetate, 105; and antimony sulphide, 265; and copper chromate, 265, 267; and gold telluride, 265, 267; and silver, antimonial sulphide of, 259, 266; and silver, metallurgy, 272; and zinc vanadate,

265; arsenate, 266; assay, 186; bismuth and antimony sulphide, 266; bismuth and silver sulphide, 258, 260, 265, 267; carbonate, mineral, 132, 186, 265; carbonate, re-agent, 105; carbonates, assay, 194; color on cupel, 249; color on scorifier, 247; copper and antimony sulphide, 262, 265; cupreous-sulphato-carbonate, 263, 265; element, 11; foil, re-agent, 102; foil, silver in, 120; glance, 131; granulated, preparation, 102; granulated, re-agent, 94, 102; granulated, silver in, 118; metallurgy, 272; minerals, 265; molybdate, 267; native, 267; ore, white, 186, 265; ore, yellow, 267; ores, 265; ores, argentiferous, 131; ores, assay, 186; ores, occurrence, 185; oxides, assay, 194; phosphate of alumina and, 267; phosphate and chloride of, 267; red oxide, mineral, 186, 266; red oxide, removal from litharge, 103; sheet, re-agent, 94, 102; sheet, silver in, 120; silver and bismuth sulphide, 258, 260, 265, 267; silver and gold telluride, 257, 266; spar, 267; sugar of, 105; sulph-antimonite, 266; sulph-arseno-antimonite, 266; sulphate, mineral, 265; sulphato-carbonate and tri-carbonate, 266

- sulphates, assay, 186; sulphide or sulphuret, assay, 186; sulphide or sulphuret, mineral, 131, 185, 266; sulphide, iron in assay of, 105, 189; telluride, 265, 266; tests for, 252; tungstate, 267; vanadate, 265; vitriol, 265; white, re-agent, 105; yellow oxide, mineral, 266; yellow oxide, re-agent, 103.
- LEADHILLITE, mineral, 266.
- LEAF gold, 129, 257; silver, 259.
- LE CONTE'S ELEMENTS OF GEOLOGY, 270.
- LEUCOPYRITES, mineral, 261.
- LIEBER'S ASSAYER'S GUIDE, 273.
- LIGHT RED SILVER ORE, 130, 259.
- LIME, sulphate of, 264.
- LIME WATER, re-agent, 110.
- LIONITE, mineral, 258, 261.
- LIPSEY CRUSHER, 19.
- LISTS AND REFERENCES, 257.
- LISTS, copper minerals, 262; dry re-agents for assaying, 93; elements, 11, 12; gold minerals, 257; lead minerals, 265; minerals carrying gold, 258; minerals carrying silver, 261; re-agents for analysis, 108; silver minerals, 258; useful books, 268; wet re-agents for assaying, 106.
- LITHARGE, properties, 104; re-agent, 94, 103; to free from red oxide, 103; silver in, 115, 116.
- LITHIUM, element, 11.
- LOCK'S WORK ON GOLD, 272.
- LOWE, F. A., reference to, 206.
- LOW'S CRUCIBLE CHARGE, 177.
- LUNAR CAUSTIC, re-agent, 110.
- LUTE, CLAY, 114.
- M.
- MAGNESIUM, element, 11.
- MAGNET, 90.
- MAGNIFYING GLASS, 90.
- MAGNOLITE, mineral, 258, 261.
- MAKIN'S MANUAL OF METALLURGY, 272.
- MALACHITE, 264; blue, 262; green, 264.
- MANGANESE, black or di-oxide, 108; briefschemer for, 254; color on cupel, 248; element, 11.
- MANIPULATION, Laboratory, books on, 270.
- MASSICOT, mineral, 266.
- MATRASSES, 79.
- MELACONITE, mineral, 180, 258, 261, 264.
- MERCURY, chloride, 110; element, 11; metallic, 110; native, 261; re-agent, 110.
- METALLIC, copper, mercury, zinc, 110; scales, 205, 207.
- METALLURGY AND MINING, books on, 271.
- METHODS, assay for copper oxides and carbonates, 182; assay for copper sulphides, 183; assay for galena, 186; assay for

- lead oxides and carbonates, 194; assay for native copper, 183; of copper analysis, 210; special, 201.
- METRIC SYSTEM, books on, 274.
- METRIC WEIGHTS, equivalents in English, 285; tables of, 283.
- MYARGYRITE, mineral, 130, 259.
- MILLER'S ELEMENTS OF CHEMISTRY, 268.
- MILL RUN, laboratory, 221.
- MIMETITE, mineral, 266.
- MINERALOGY, books on, 270.
- MINERALS, assaying of, in an ore 201; copper, 262; gold, 257; lead, 265; likely to carry gold, 258; likely to carry silver, 261; silver 258.
- MINERS' gold-washing pans, 91, 227.
- MINING LAW, books on, 274.
- MINIUM, mineral, 186, 266.
- MISCELLANEOUS apparatus, 81.
- MITCHELL, references to, 6, 37, 46, 59, 74, 103, 104, 184, 197, 242, 246, 247.
- MITCHELL'S MANUAL OF PRACTICAL ASSAYING, 6, 273.
- MOISTURE in ores, determination of, 255.
- MOLYBDATE OF LEAD, mineral, 267.
- MOLYBDENUM, element, 11.
- MORFIT'S CHEMICAL MANIPULATIONS, 270.
- MORTAR, amalgamation, 91, 223.
- MORTARS AND PESTLES; glass, 81; iron, 18; porcelain, 81.
- MOSANDRIUM, element, 12.
- MOULDS; cupel, 88; ingot, 90; scorifier, scorification or slag, 65.
- MOUNTAIN blue, 262, 263; green, 263, 264.
- MUFFLE floors, 69; hoe or rake 64; scraper, 67; shovel, 64.
- MUFFLES, 68.
- MÜLLERITE, mineral, 257, 261, 266.
- MULTIPLICATION TABLE FOR GOLD AND SILVER, 279.
- MURIATE of barium, 109; of copper, 262; of silver, 259.
- MURIATIC ACID, 109.
- MYERS' "JEWEL" ASSAY APPARATUS, 49.
- N
- NAGYAGITE, mineral, 257, 261, 267.
- NAILS, iron, re-agent, 94, 105.
- NATIVE antimony, 261; arsenic, 258, 261; bismuth, 258, 261; copper, 180, 261, 264; copper, assay, 183; gold, 129, 257, 261; lead, 267; mercury, 261; silver, 258, 259; tellurium, 258, 261.
- NEEDLE ORE, mineral, 262.
- NICKEL, cobalt and copper, sulphide, 263; element, 11.
- NITRATE OF SILVER, re-agent, 110.

NITRE, oxidizing power, 115, 122; re-agent, 94, 99.

NITRIC ACID, preparation of various strengths, 162; re-agent, 107, 110; to free from chlorine, 107.

NITROGEN, element 11.

NORTH'S PRACTICAL ASSAYING, 273.

NORWEGIUM, element, 12.

NOTE-BOOKS, 81, 133.

NUGGET GOLD, 129, 257.

## O.

OCHRE, PLUMBIC, 266.

OCCURRENCE OF ORES, copper, 180; gold, 129; gold and silver, 129; lead, 185; silver, 130.

OERTLING'S BULLION BALANCE, 35.

OIL CLOTH for sampling, 82.

OIL OF VITRIOL, re-agent, 113.

ORDER OF WORK IN SCORIFICATION PROCESS, 141.

ORE, argentiferous gray copper, 131; arsenical silver, 259; assaying of minerals in, 201; azure copper, 262; brittle silver, 130; dark red silver, 130, 260; gray copper, 181, 260, 264; green copper, 264; green lead, 266; light red silver, 130, 259; needle, 262; purple copper, 262, variegated copper, 262; white lead, 186, 265; yellow lead, 267.

ORES, analysis of copper, 210; argentiferous lead, 131; "carbonate," 129; charge for testing, 124; "chloride," 131; chlorination assay of gold, 234; containing free gold or silver, assaying of, 203; copper, 262; copper, assay, 181; copper, occurrence, 180; determination of moisture in, 255; directions for sampling, 135; gold, 129; gold, assay, 132; gold, occurrence, 129; gold and silver, 129; gold and silver, assay, 132; gold and silver, occurrence, 129; important silver, 130; lead, 185; lead, assay, 186; lead, occurrence, 185; pulverizing, 18, 21, 137; reducing powers of, 116, 123; silver, 130; silver, assay, 132; silver, occurrence, 130; tellurium, 129; volumetric analysis of copper, 220.

OSMIUM, element, 12.

OUTFIT, assaying, 276.

OVERMAN'S ASSAYING, 273.

OXIDE, antimony, 260; copper, 180, 182, 264; copper, black, 180, 264; copper, red, 180, 263; cupric, 264; cuprous, 263; iron, 129; iron, red, 114; lead, red, mineral, 186, 266; lead, red, to remove from litharge, 103; lead, yellow, mineral, 266; manganese, black, 108; yellow, re-agent, 103; uranium, 264.

OXIDES, copper, assay, 182; iron, silica for, 170; lead, assay, 194.  
 OXIDIZING action of bi-carbonate of soda, 94; action of nitre, 99; power of nitre, 115, 122.  
 OXY-CHLORIDE OF COPPER, mineral, 262.  
 OXYGEN, element, 11.

## P

PALLADIUM, color on cupel, 248; element 11.  
 PAN TEST or "panning" for gold, 225.  
 PANS, frying, 87; miners' gold-washing, 91, 227; zinc sifting, 26.  
 PAPERS, black glazed, 82; blotting, 83; brown or Manilla, 82; filter, 83; tissue, 83.  
 "PARTING," 141, 161.  
 PARTING-FLASKS, 79.  
 PERCY'S METALLURGY, 272.  
 PERMANENT FURNACES, 59.  
 PETZITE, mineral, 257, 259, 261.  
 PHILIPPUM, element, 12.  
 PHILLIPS' ASSAYERS' COMPANION, 273.  
 PHOSPHATE and chloride of lead, 267; of alumina and lead, 267; of copper, 264; of uranium and copper, 264.  
 PHOSPHORUS, element, 12.  
 PINCERS, 83.  
 PIPETTES, 81.  
 PLATE, annealing, 76; gem, 66; pouring, 65; pulverizing, 21.

PLATINUM; color on cupel, 248; dish, 214; element, 12; spatulas, 27.  
 PLATTNER'S BLOW-PIPE ANALYSIS, 271.  
 PLUMBIC, acetate, re-agent, 105; carbonate, re-agent, 105; monoxide, re-agent, 103; ochre, 266.  
 PLUMBOGUMMITE, mineral, 267.  
 PLYMPTON'S BLOW-PIPE DETERMINATION, 271.  
 POKERS, 67.  
 POLYBASITE, mineral, 130, 259.  
 PORCELAIN and glass apparatus, 77; casserole, 81; crucibles or capsules, 78, 161; mortars, 81; spatulas, 27.  
 POTASH carbonate, 93, 95; caustic or hydrate, 108; cyanide, 93, 95; bi or di-chromate, 108; bi-tartrate, 98, 121; ferrocyanide, 109; iodide, 109; nitrate, 94, 99, 115, 122; sulphocyanide, 111; yellow prussiate, 109.  
 POTASSIUM, element, 12.  
 POURING PLATES, 65.  
 PRECIPITATED SILICA, re-agent, 101.  
 PREFACE, 5.  
 PRELIMINARY WORK, 115.  
 PREPARATION OF borax glass, 97; charge in scorification process, 141; granulated lead, 102; samples, 133; various strengths of nitric acid, 162.

PROCESS, crucible, 133, 170;  
 scorification, 133, 139.  
 PROTO-CHLORIDE OF TIN, re-  
 agent, 111.  
 PROUSTITE, mineral, 259.  
 PRUSSATE OF POTASH, yellow,  
 109.  
 PSEUDOMALACHITE, mineral, 264.  
 PULPS, scales for, 28.  
 PULVERIZING of ores, 18, 21,  
 137; sampling, etc., imple-  
 ments for, 18, plate and rub-  
 bers, 21; plate and rubbers,  
 manner of using, 23.  
 PURPLE COPPER ORE, 262.  
 PYRARCYRITE, mineral, 260.  
 PYRITE, mineral, 258, 261.  
 PYRITES, argentiferous, 132; cop-  
 per, 263; iron and copper, 129,  
 132.  
 PYROMORPHITE, mineral, 267.

## Q

QUALITATIVE ANALYSIS, Douglas  
 and Prescott's, 269; Eliot and  
 Storer's, 269; Fresenius', 255;  
 general, books on, 269.  
 QUALITATIVE TESTS, 249; car-  
 bonates, 249; copper, 251; iron,  
 251; lead, 252; silver, 252;  
 sulphates, 250; sulphides, 250;  
 tellurides, 250.  
 QUANTITATIVE ANALYSIS, Cairns',  
 269; Classen's, 269; Fresenius',  
 255; general, books on, 269;  
 Rammelsberg's, 269; special,  
 books on, 269; Wöhler's, 269.

## R

RAKE, cupel, 64.  
 RAMMELSBERG'S QUANTITATIVE  
 ANALYSIS, 269.  
 RE-AGENTS, dry, for assaying, 93;  
 for analysis, 108; in scorifica-  
 tion process, 140; testing of,  
 115; wet, for assaying, 106.  
 REALGAR, mineral, 261.  
 RED OXIDE OF copper, 180, 263;  
 iron, 114; lead, mineral, 186,  
 226; lead, removal of, from  
 litharge, 103.  
 REDUCING POWER OF, argol, 121;  
 charcoal, 122; cream of tartar,  
 121; ores, 116, 123; reducing  
 agents, 115, 121.  
 REFERENCE BOOKS ON CHEMIS-  
 TRY, 268.  
 REFERENCES AND LISTS, 257.  
 REFERENCES TO Am. Inst. of Min.  
 Eng., 211; Attwood, 227; Aus-  
 tin, L. S., 134, 245; Bodemann  
 and Kerl, 184; Dana, 267; Eg-  
 gleston, T., 285; Eng. and Min.  
 Jour, 134, 206, 243; Eustis, W.  
 E. C., 211; Fresenius, 255; Hart,  
 255; Kustel, 6, 130, 235, 237,  
 239; Lowe, F. A., 206; Mitch-  
 ell, 6, 37, 46, 59, 74, 103, 104,  
 184, 197, 242, 246, 247; North,  
 247; Ricketts, 6, 59, 122, 124,  
 155, 176, 184, 191, 204, 237;  
 Smith, J. A., 267; Sutton, 255;  
 Triplett, 247, 248.  
 REPORT ON COLORADO MINER-  
 ALS, 267.

REPORT ON SILVER BULLION  
WASTAGE, 239  
RESIDUES, GOLD, weighing of,  
141, 165.  
RETORTING in scorifiers, 224.  
RETORTS, iron, 92.  
RHODIUM, element, 12.  
RICKETTS, charge for copper sul-  
phides, 184; charge for galena,  
191; charge for nitre, 122;  
charge for pyrites, 176; Notes  
on Assaying, 6, 273; references  
to, 6, 59, 122, 124, 155, 176, 184,  
191, 204, 237.  
RING STAND, 86.  
ROASTING, carbonate of ammo-  
nia used in, 143; charcoal used  
in, 144; of ores in crucible pro-  
cess, 171; dishes, 71; of ores in  
scorification process, 141; sili-  
ca used in, 143.  
ROLLS, 90.  
ROSCOE and Shorlemmer's, Chem-  
istry, 268; Elementary Chem-  
istry, 269. .  
ROUND CRUCIBLES, 70.  
RUBBER, sheet or cloth, 82.  
RUBBING PLATE, 21.  
RUBIDIUM, element, 12.  
RUBY SILVER, mineral, 130, 259,  
260.  
RUDDLE, 114.  
RUTHENIUM, element, 12.  
RUTLEY'S STUDY OF ROCKS, 270.

## S

SALT, COMMON, re-agent, 94, 99.

SALTPETRE, re-agent, 94, 99  
SALTS, TIN, re-agent, 111.  
SAMARIUM, element, 12.  
SAMPLE bottles, 77, 134; boxes,  
82, 134; preparation of, 133;  
shovels, 24.  
SAMPLERS, 24.  
SAMPLES, to obtain average, 134.  
SAMPLING OF BASE BULLION, 245.  
SAND BATHS, 87; crucibles, 70;  
in accidents to muffles, 150;  
re-agent, 101.  
SCALES and balances, 28; hand,  
31; pulps and fluxes, 28.  
SCALES, METALLIC, 205, 207.  
SCANDIUM, element, 12.  
SCHAPBACHITE, mineral, 260, 267.  
SCHEME FOR SILICA, IRON AND  
MANGANESE, 254.  
SCHIRMERITE, mineral, 260, 267.  
SCIENCE, GENERAL, books on, 268.  
SCISSORS, 90.  
SCORIFICATION, color tests, 246;  
moulds, 65; tongs, Judson's, 62.  
SCORIFICATION PROCESS, 133, 139;  
borax glass in, 140; buttons  
from, 148; calculations, 141,  
166; charges, 167; cupellation,  
141, 153; granulated lead in,  
140; inquartation, 141, 164;  
order of work, 141; parting, 141,  
161; preparation of charge, 141;  
re-agents used for, 140; roasting  
of ores in, 141; scorification, 141,  
146; scorifiers from, 150; silica  
in, 141; slag from, 149; theory  
of, 140; weighing gold and sil-

- ver bead, 141, 160; weighing gold residues, 141, 165.
- SCORIFIER, color tests, 247; moulds, 65; tongs, 61.
- SCORIFIERS, 72; "retorting" in, 224.
- SCRAPER, MUFFLE, 67.
- SELENIUM, element, 12.
- SEPARATORY FUNNEL, 80, 236.
- SESQUIOXIDE, FERRIC, re-agent, 114.
- SHEARS, 90.
- SHEET lead, re-agent, 94, 102; testing for silver, 120; rubber, for sampling, 82.
- SHOVELS, cupel, 64; sample, 24.
- SIEVES, 26; box, 26.
- SIFTING of ores, 137; pans, 26.
- SILICA, acid flux, 101; brief scheme for, 254; in scorification process, 140, 143; precipitated, 101; re-agent, 94, 101.
- SILICATE OF COPPER, mineral, 263.
- SILICIC DI-OXIDE, re-agent, 101.
- SILICON, element, 12.
- SILVER and antimony sulphide, 130, 259, 260; and copper sulphide, 131, 260, 264; and gold, metallurgy, 272; and gold multiplication table, 279; and gold values, table of, 280; and gold telluride, 257, 259, 260; and gold ores, assaying, 132; and iron sulphide, 260; and lead, antimonial sulphide of, 259, 266; and lead, metallurgy, 272; antimonial, 130, 259, 260; antimony and arsenic sulphide, 130, 259; arsenical, 259; assay, 132; assaying of ores containing free, 203; bismuth, 260, 267; bismuth and lead sulphide, 258, 260, 265, 267; black, 260; brittle, 130, 260; bromic or bromide of, 131, 258; bullion, report on wastage, 239; chloride, 131, 259; chlorination test for, 237; chlorobromide, 259; copper glance, 131, 260, 264; dark red, 130, 260; dendritic, 259; element, 12; fahlore, 131; foil, gold in, 105; foil, re-agent, 94, 105; free, 259; glance, 130, 258; gold and lead telluride, 257, 266; horn, 130, 259; in granulated lead, 115, 118; in lead foil, 120; in litharge, 115, 116; iodine or iodide of, 131, 259; leaf, 259; lead and bismuth sulphide, 258, 260, 265, 267; light red, 130, 259; metallurgy, 272; minerals carrying silver, 260; minerals in U. S., 258; muriate, 259; native, 258; nitrate, re-agent, 110; ores, 130; ores, assaying, 132; ores, important, 130; ores, occurrence, 130; ruby, 130, 259, 260; spatulas, 27; sulphide or sulphuret, 130, 258; telluric or telluride of, 259; test for, 252; testing of granulated lead for, 118; testing of litharge for,



- 116; testing of sheet lead for, 120; vitreous, 258; wire, 259.
- SILVERSMITH'S HAND-BOOK FOR ASSAYERS, 274.
- SLAG from scorification process, 149; moulds, 65.
- SMALTITE, mineral, 261.
- SMITH, J. A., reference to, 267; Report on Colorado Minerals, 267.
- SODA, bi-carbonate of, 93, 94.
- SODIC bi-borate, re-agent, 93, 96; chloride, 99; hyposulphite, 109, 238.
- SODIUM, element, 12.
- SPAR, calc, 178; fluor, 178; heavy, 178; yellow lead, 267.
- SPATULAS, 27.
- SPECIAL directions for bullion balances, 37; methods, 201; quantitative analysis, books on 269.
- SPHALERITE, mineral, 258, 261.
- "SPITTING," 157.
- SPOONS, HORN, 28.
- "SPROUTING," 157.
- STAND, filter, 91; ring, 86.
- STANNOUS CHLORIDE, re-agent, 111.
- STEEL alphabets and figures, 90; spatulas, 27.
- STEPHANITE, mineral, 130, 260.
- STERNBERGITE, mineral, 260.
- STETEFELDTITE, mineral, 131, 260.
- STIRRING RODS, glass, 80; wire, 142.
- STOLTZITE, mineral, 267.
- STONE'S universal flux, 178.
- STOVES, 87.
- STROMEYERITE, mineral, 131, 260, 234.
- STRONTIUM, element, 12.
- SUBLIMATE, corrosive, re-agent, 110.
- SUGAR OF LEAD, re-agent, 105.
- SULPH-ANTIMONITE OF LEAD, mineral, 266.
- SULPH-ARSENITE OF COPPER, mineral, 263, 264.
- SULPH-ARSENO-ANTIMONITE OF LEAD, mineral, 266.
- SULPHATES, copper, 262, 263; iron, 111; lead, 265; lime, 264; test for, 250.
- SULPHATO-CARBONATE, and tri-carbonate of lead, 266.
- SULPHIDES or SULPHURETS. auriferous, 129; bismuth, silver and lead, 258, 260, 265, 267; cobalt, nickel and copper, 263; copper, 181, 263; copper and iron, 181, 262, 263; copper, lead and antimony, 262, 265; ferrous, re-agent, 111; iron, re-agent, 111; iron and copper, 181; lead, 131, 266; lead and antimony, 265; lead, bismuth and antimony, 266; lead, iron in assay of, 139; roasting of, 142, 171; silver, 130, 258; silver and antimony, 130, 259, 260; silver and copper, 131, 260, 264; silver and iron, 260; silver and lead, antimonial,

- 259, 266; silver, antimony and arsenic, 259; test for, 250; zinc, 132.
- SULPHOCYANIDE OF POTASSIUM, re-agent, 111.
- SULPHUR, element, 12; vapors, color of, 246.
- SULPHURETTED HYDROGEN, preparation, 111.
- SULPHURETS, AURIFEROUS, 129.
- SULPHURIC ACID, re-agent, 113.
- SUTTON, reference to, 255.
- SUTTON'S VOLUMETRIC ANALYSIS, 255, 270.
- SYLVANITE, mineral, 257, 260, 261.
- T
- TABLES, 279; avoirdupois wgt., 281; apothecaries' wgt., 282; assay ton weights in grammes, grains, etc., 286; equivalents of English and French weights, 285; French or metric weights, 283; multiplication for gold and silver, 279; Troy weights, 282; values of gold and silver, 280; weights, 281.
- TANTALUM, element, 12.
- TARTAR, cream of, re-agent, 98.
- TECHNOLOGY, CHEMICAL, Wagner's, 268.
- TELLURIC SILVER, mineral, 259.
- TELLURIDES, by crucible process, 178; by scorification process, 169; gold, 257; gold and lead, 257, 267; gold and silver, 257, 259, 260; gold, silver and lead, 257, 266; lead, 265, 266; silver, 259; test for, 250.
- TELLURITE, mineral, 258, 261.
- TELLURIUM, black, 257, 267; color on scorifier, 247; element, 12; foliated, 257, 267; graphic, 257, 260; native, 258, 261; ores, 129; yellow, 257, 260.
- TELLURPYRITE, mineral, 258, 261.
- TENNANTITE, mineral, 264.
- TERBIUM, element, 12.
- TESTING OF distilled water for chlorine, 106; granulated lead for silver, 115, 118; litharge for silver, 115, 116; re-agents, 115; sheet lead for silver, 115, 120; silver foil for gold, 105.
- TESTS, chlorination for silver, 237; cupel color, 247; scorification color, 246; scorifier color, 247; qualitative for carbonates, chlorides, copper, iron, lead, silver, sulphates, sulphides, tellurides, 249.
- TEST-TUBES, 79.
- TETRADYMIT, mineral, 258, 261.
- TETRAHEDRITE, mineral, 181, 258, 260, 264.
- TEXT-BOOKS ON theoretical chemistry, 268.
- THALLIUM, element, 12.
- THEORY OF crucible process, 174; scorification process, 140.
- THORIUM, element, 12.
- THULIUM, element, 12.

TIN, color on cupel, 248; element, 12; proto-chloride, or "tin salts," 111.

TISSUE PAPER, 83.

TITANIUM, element 12.

TONGS, crucible, 59; cupel, 62; scorifier, 61.

TOOLS, FURNACE, 59.

TORBERNITE, mineral, 264.

TREATISE ON Chemistry, Roscoe and Schorlemmer's, 268; Ore Deposits, Cotta's, 270.

TRIANGLE, WIRE, 86.

TRIANGULAR CRUCIBLES, 70.

TRIPLE SULPHURET OF COPPER, LEAD AND ANTIMONY, 262, 265.

TRIPLETT, references to, 247, 248.

TRIPLETT'S HOW TO ASSAY, 274.

TROEMNER'S bullion balances, 33-4-5; pulp scales, 29.

TROY WEIGHTS, tables of, 282.

TUBES, TEST, 79.

TUNGSTATE OF LEAD, mineral, 267.

TUNGSTEN, element, 12.

## U

UNITED STATES, minerals found in; copper, 262; gold, 257; lead, 265; silver, 258.

UNIVERSAL FLUX, Stone's, 178.

URANIUM and copper, phosphate, 264; element, 12; oxide, 264.

URANOCHALCITE, mineral, 264.

USEFUL BOOKS, list of, 268.

## V

VALUES OF GOLD AND SILVER, table of, 280.

VANADATE OF LEAD, 265; and zinc, 265.

VANADIUM, element, 12.

VARIEGATED COPPER ORE, 262.

VAUQUELINITE, mineral, 265, 267.

"VEGETATING," 157.

VITREOUS copper, 263; silver, 258.

VITRIOL, blue, 263; copper, 263; green, 111; lead, 265; oil of, 113.

VOLUMETRIC ANALYSIS of Copper Ore, 220; Hart's, 255, 270; Sutton's, 255, 270.

## W

WADE'S MINING LAW, 274.

WAGNER'S CHEMICAL TECHNOLOGY, 268.

WASH-BOTTLE, 78.

WASH, CHALK, 114.

WASTAGE, SILVER BULLION, Report on, 239.

WATCH-GLASSES, 31, 78.

WATER, ammonia, 108; distilled, chlorine in, 106; lime, 110; reagent, 106; sulphuretted hydrogen, 111.

WATTS' DICTIONARY OF CHEMISTRY, 268.

WEHLITE, mineral, 258, 261.

WEIGHING gold and silver beads,

- 141, 160; gold and silver beads, balances for, 32; gold residues, 141, 165.
- WEIGHTS**, 39; and measures, Eggleston's, 274; apothecaries', tables, 282; assay ton, 40; assay ton, explanation of, 41; assay ton, in grammes, grains, etc., 286; avoirdupois, tables, 281; equivalents of French and English, 285; French, metric or gramme, 39, 40; French or metric, tables, 283; "gold," 42, 240; grain, 41; tables of, 279; Troy, tables, 282.
- WET RE-AGENTS FOR ASSAYING**, 106.
- WHITE LEAD** ore, 186, 265; re-agent, 105.
- WHITNEYITE**, mineral, 265.
- WILLIAMS' CHEMICAL MANIPULATIONS**, 270.
- WILSON'S MINING LAWS** of U. S., 274.
- WINDOW GLASS**, as re-agent, 101.
- WIRE** gauze, 87; gold, 129, 257; iron, re-agent, 94, 105; silver, 259; stirring, 142; triangle, 86.
- WÖHLER'S MINERAL ANALYSIS**, 269.
- WOOD CHARCOAL**, properties, 99; re-agent, 94, 99; reducing power, 122.
- WORK**, order of, in scorification process, 141; preliminary, 115.
- WULFENITE**, mineral, 267.
- Y**
- YELLOW** lead ore or spar, 267; oxide of lead, mineral, 266; oxide of lead, re-agent, 103; prussiate of potash, re-agent, 109; tellurium, 260.
- YTTERBIUM**, element, 12.
- YTTRIUM**, element, 12.
- Z**
- ZINC** and copper carbonate, 262; and lead vanadate, 265; blende, argentiferous, 132; color on cupel, 248; color of vapors, 246; element, 12; in battery, 110, 216; metallic, re-agent, 110; sifting-pans, 26; sulphide or sulphuret, 132.
- ZIRCONIUM**, element, 12.

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